1997

Increasing cognitive functioning in science for English language learners

Deborah Sue Powell

INCREASING COGNITIVE FUNCTIONING IN SCIENCE FOR ENGLISH LANGUAGE LEARNERS

A Project

Presented to the

Faculty of

California State University,

San Bernardino

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

in

Education:

Teaching English as a Second Language

---

by

Deborah Sue Powell

June 1997

INCREASING COGNITIVE FUNCTIONING IN SCIENCE FOR ENGLISH LANGUAGE LEARNERS

A Project

Presented to the

Faculty of

California State University,

San Bernardino

---

by

Deborah Sue Powell

June 1997

Approved by:

[redacted] 6/12/97

Lynne Díaz-Rico, First Reader Date

[redacted]

Joseph Jesunathadas, Second Reader

ABSTRACT

This project illustrates the dynamic assessment of science thinking by presenting case studies of three young learners whose cognitive academic language proficiency and cognitive functions were explored in an after-school science program at an elementary school. The study of these learners suggests strategies that science teachers might include for increasing students' cognitive functioning and science process thinking. The project includes reproducible pages that assist teachers in assessing and supporting students' cognitive functions, science processes, and cognitive academic language proficiency using a dynamic assessment approach in conjunction with Full Option Science System activities.

ACKNOWLEDGMENTS

My sincere gratitude and thanks go to Dr. Lynne Díaz-Rico for her continued support and guidance.

Thanks also to Dr. Joseph Jesunathadas, whose insights and support into the science portions of this project were most valuable.

Lastly, my deepest thanks and love to my family for their continual support of my work and their undying faith that this project would come to an end.

TABLE OF CONTENTS

ABSTRACT.....iii

ACKNOWLEDGMENTS..... iv

LIST OF TABLES.....viii

CHAPTER ONE: INTRODUCTION

Background of the Project..... 1

Purpose of the Project..... 4

Content of the Project..... 5

Significance of the Project..... 6

CHAPTER TWO: LITERATURE REVIEW

Current Guidelines for Elementary Science Instruction..... 8

Full Option Science System..... 10

Inadequacies of FOSS..... 15

Science Processes..... 16

Observing..... 19

Communicating..... 19

Comparing..... 20

Ordering..... 20

Categorizing..... 20

Relating..... 21

Inferring..... 22

Applying..... 22

Controlling Variables..... 23

Defining Operationally..... 23

Formulating Hypotheses..... 24

Interpreting Data..... 24

Experimenting..... 25

Cognitive Academic Language Proficiency..... 26

Vocabulary..... 28

Word Choice..... 29

Formulaic Language..... 29

Logical Structure and Format..... 30

Cognitive Academic Language Learning Approach..... 31

Language Functions..... 32

Instrumental..... 32

Regulatory..... 33

Representational..... 33

Interactional..... 33

Personal..... 34

Heuristic..... 34

Imaginative..... 34

Cognitive Functions..... 34

Input..... 36

Elaboration..... 39

Output..... 42

Critical Thinking..... 44

Clarity..... 45

Basis..... 47

Inference..... 48

Strategies and Tactics..... 49

Triarchic Theory of Intelligence..... 51

Metacomponents..... 51

Performance Components..... 52

Knowledge-Acquisition Components..... 54

Assessment..... 56

Standardized Testing..... 57

Dynamic Assessment..... 59

CHAPTER THREE: THEORETICAL FRAMEWORK

Exploration..... 74

Elaboration..... 77

Extension..... 84

CHAPTER FOUR: SCIENTIFIC TALENT ENRICHED PERFORMANCE SYSTEM..... 88

Miriam..... 93

Sean..... 96

Michelle..... 99

Summary.....102

CHAPTER FIVE: RECOMMENDATIONS TO TEACHERS WHO USE FOSS 104

APPENDICES.....106

Appendix A: Cognitive Functions Correlation to FOSS Models and Designs Black Boxes Activity.....108

Appendix B: Activities to Support English Language Learners.....135

Appendix C: Tools for Teachers.....144

REFERENCES.....151

LIST OF TABLES

Table 1. Comparison of Science Processes..... 65

Table 2. Cognitive Academic Language Learning Approach..... 67

Table 3. Language Functions..... 68

Table 4. Cognitive Functions..... 69

Table 5. Critical Thinking..... 70

Table 6. Triarchic Theory of Intelligence..... 72

CHAPTER ONE: INTRODUCTION

Background of the Project

Educators are currently attempting to modify educational programs to better prepare students for their futures in the changing world. As technology and science gain an increasingly important place in everyday life, it is imperative that more people become scientific thinkers and communicators. In order to live in a highly technological world, one must be able to reason, think, and communicate about science and related issues. Unless students are able to attain the necessary skills and strategies of higher level thinking and problem solving, they are not likely to be able to manage the increasingly rigorous academic requirements they will face in higher education.

Educators must provide for students the highest quality scientific experiences, building the foundation upon which reasoning, thinking, and communicating skills will develop. Students must be able to communicate with enough competence to understand directions, discuss issues with peers, explain coherently, and solve problems. High quality lessons and experiences in science include hands-on, multi-sensory activities which are accessible and understandable to all students. Unfortunately, this quality of instruction is not a reality in many schools. Many teachers are overwhelmed by the task of educating a highly diverse student population.

An ever-increasing population of non-English speakers impacts the U.S. American educational system. "The highest number, by far, is found in California, with over one million limited-English-proficient (LEP) students in 1992, over one in five of the total California student population" (Díaz-Rico and Weed, 1995, p. 222). Many of these children enter U.S. American schools with a limited vocabulary, often split between two languages (Cohen, 1994). For English language learners (ELLs) an accessible, understandable science program is often not available.

For the teacher in an English-as-a-second-language (ESL) classroom, the demands are complex. Educators in California are required to deliver a curriculum guided by state frameworks, district guidelines, and school plans. Most science programs available to California educators fall short in providing adequate support for ELL students. A brief paragraph per lesson might be found in the teacher's guide books offering educators encouragement to "proceed slowly when explaining" key vocabulary, as is the case in Scholastic's Science Place, (1993). This level of instructional modification is simply not adequate to insure the success of ELL students.

Not only must educators deliver the required curriculum, they must also see to it that all students understand and learn the content. Incorporating concept

development and language instruction into developmentally and culturally appropriate lessons requires that teachers not only try to explain the assignments, but also work to remediate basic literacy skills and linguistic competence (Cohen, 1994).

Sadly, many English language learners are too readily labeled as slow or deficient learners. Feuerstein (1980) believes that the problem lies with the expectations of teachers and parents, rather than with the learner. Teachers and parents need to understand that "the child's major problem is the quality of the instruction received in the past rather than a lack of ability" (Feuerstein, 1980). Once teachers and parents change their points of view about why some children do not achieve in the classroom, students may learn more rapidly and effectively.

Educators can create powerful learning programs for English language learners when they combine instruction in English with instruction in science. "For English to serve as a medium of science learning for LEP students, integration of language and science content requires organizing science experiences in specific ways to facilitate development of both language and cognitive processes" (Kessler, Quinn, & Fathman, 1992, p. 66). The organization of a program which combines instruction in science and English will be supported by an understanding of

theories related to science teaching and learning, language teaching and learning, and cognition. Teachers who are trained in Crosscultural, Language, and Academic Development (CLAD) have such a theoretical background, and are able to develop educational experiences which blend content area instruction with instruction in English.

Purpose of the Project

The primary goal of any English-as-a-second-language (ESL) program is to develop the learner's ability to read, write, listen, and speak English fluently. Additionally, ESL educators must insure that their students are receiving the same content-rich curriculum offered to English-only students. This project will specifically address students' needs for meaningful content combined with understandable language that encourages critical thinking within the context of instruction in science.

The purpose of the project is to explore ways to provide all students, including English language learners, with instruction which will enable them to realize their full developmental and educational potential in science. This project illustrates the dynamic assessment of science thinking by presenting case studies of three students whose cognitive academic language proficiency and cognitive functions were explored in an after-school science program at an elementary school. The study of these learners

suggests strategies that science teachers might employ for increasing students' science process thinking. The intent is to design a resource guide for elementary teachers which will assist them in assessing and supporting students' cognitive functions and cognitive academic language proficiency using a dynamic assessment approach in conjunction with Full Option Science System (FOSS) activities. These strategies may also be applied to other FOSS modules, and eventually to other domains of instruction.

Specifically, the purposes of the project are to; first, provide teachers with a format which helps them facilitate the assessment and support of students' cognitive functions and process thinking in science (see Appendix A, p. 108). Second, the resource guide will include strategies which will increase cognitive academic language proficiency for English language learners within the science curriculum (see Appendix B, p. 135). Third, it will supply teachers with reproducible pages useful in identifying cognitive functions and monitoring student achievement in science (see Appendix C, p. 144).

Content of the Project

In Chapter One, an overview of current instructional challenges facing educators with a rapidly increasing non-English speaking student population is introduced. In

Chapter Two, related literature is reviewed to provide an orienting framework for the teacher's resource guide. The literature review includes a description of science process skills, cognitive academic language proficiency, cognitive functions, and dynamic assessment strategies. In Chapter Three, a set of guiding theories for the resource guide is proposed. In Chapter Four, dynamic assessment interactions with three students are illustrated. In Chapter Five, recommendations for implementing the dynamic assessment of cognitive functions in science content are presented. Finally, the resource guide presented in the appendices provides teachers with background information, ESL instructional strategies for FOSS science lessons, and suggestions for implementation of dynamic assessment strategies.

Significance of the Project

The importance of teaching students to be thinkers and speakers in science extends beyond the school setting. Students who are able to reason, think, and communicate about scientific issues will benefit in all areas of their lives. The educator's responsibility is to provide a curriculum which fosters critical thinking in academic content areas for all students, including English language learners, as well as other educational minority students.

It is hoped that the resource guide will assist all educators, not just those who work with English language learners. The resource guide is intended to provide science educators a means of identifying and increasing students' critical thinking and use of science processes when conducting FOSS science lessons for all students, especially English language learners. These strategies might then be adapted and modified by educators so that they could be applied to other science units or different curricular areas.

CHAPTER TWO: LITERATURE REVIEW

Many thinkers have explored the ways children process information and learn language. Some areas of recent interest include science processes, cognitive academic language proficiency, cognitive functions, critical thinking, and assessment of cognitive abilities. This chapter will explore these topics and analyze their implications on science instruction for English language learners.

Current Guidelines for Elementary Science Instruction

Children come to the classroom with a natural curiosity about the world around them. They are natural questioners, wonderers, and thinkers. The challenge is, then, for educators to harness that natural inquisitive nature and guide it toward academic understandings of the world. It is not enough for children to simply "do science." Following lesson procedures as one would follow the steps on a recipe card does not guarantee that children will gain an understanding of science concepts presented by the teacher. Current curricular programs exhort teachers to use a wide variety of activities, labs, demonstrations, and other investigations to develop the concepts as well as the processes of science. Doing science must include more than merely following directions; students must be cognitively engaged and encouraged to use science processes.

It is recommended in The Science Framework for California Public Schools (hereafter denoted as Science Framework), (1990) that 40% of the total time spent learning science be hands-on activities. This sentiment is presented elsewhere, as well. "Activity-based instruction also gives students a vastly more robust insight into how science works. And it provides learnings that students are far more likely to retain" (It's Elementary!, 1992, p. 26).

Realistically, implementing activity-based, hands-on activities takes longer than does simply reading a few paragraphs from a science text. "Providing learning experiences in which the understanding of concepts is the goal takes more time than passing along bits and pieces of information" (It's Elementary!, 1992, p. 25). Therefore, the number of topics which can be addressed will decrease. To put it succinctly, less is more. Fewer topics covered in a more in-depth study will be of greater value to students than simply reading a science chapter and answering the questions which inevitably come at the end of the chapter. The emphasis should therefore be that students learn science content, balanced with science processes and critical thinking skills. English language learners face the additional challenge of increasing their English proficiency while at the same time increasing their understanding of content areas such as science.

U.S. Secretary for Education, Tarey Reilly, summarizes the many benefits of using science instruction as a means of developing English language learners' English proficiency. "Content-based ESL programs have been developed to provide students with an opportunity to develop their cognitive academic language proficiency" (Reilly, 1988).

Reilly describes a set of ideas which show how English language development is achieved through science. Science provides a rich context for genuine language use. Specifically, it offers interesting, relevant, and challenging content. Lessons and activities in science provide opportunities for students to receive an abundance of comprehensible language input, working cooperatively with peers to negotiate meanings. Reilly noted that science can provide a focal point for oral language and literacy development. Science lessons can offer materials for the development of reading, writing, and authentic experiences with English.

Full Option Science System

Throughout California, the educational excellence movement has renewed an interest in science education. The current trend in education indicates that an integrated approach to curriculum (combining two or more content areas to produce lessons which are related to each other) is more meaningful to children. By integrating science concepts

with other curricular areas, students are offered more opportunities for gaining a wider understanding of the topic. Integrated units might include a combination of math, science, and language arts lessons. This allows students more exposure to related concepts and ideas, and often allows teachers to extend activity times to up to two hours, which enables students to accomplish more in-depth study. For example, exploration by students who are actually testing materials in water to "discover" which items sink or float creates a more learning-rich arena when studying the concept of buoyancy than does the older curriculum teaching strategy of reading the text and regurgitating the information on a paper and pencil test. When children are engaged in integrated and developmentally appropriate programs, their "on-task" behavior goes up and learning is increased (Day & Drake, 1986).

Although integrating science with other curricular areas can provide a sense of connection and continuity for students, teachers must be careful to maintain the integrity of the science program itself. A strong emphasis on the value of science as an independent domain must be maintained in the classroom.

The Full Option Science System (FOSS) is a nationally recognized K-6 science curriculum which is available to science educators in California as a state-adopted science

program. The activities and lessons in the FOSS curriculum are consistent with the recommendations made in California's Science Framework (1990) regarding hands-on activities in science.

> The best way for students to appreciate the scientific enterprise, learn important scientific concepts, and develop the ability to think well, is to engage them directly in situations in which they actively construct their own explorations, investigations, and analyses. The Full Option Science System was created to accomplish this task. (Encyclopaedia Britannica Educational Corporation [hereafter denoted as Britannica], 1992, p.4).

FOSS is a modular program, meaning that content is organized in self-contained units that work together to create a series of quality science experiences. For instance, the Models and Designs unit is housed in a kit that has all the necessary concrete science materials, teacher guides, assessment items, and original blackline masters for duplicating student worksheets.

The modules designed for grades kindergarten through two are organized under three topic headings: Life Science, Physical Science, and Earth Science. The modules designed for grades three through six are organized under the same three headings, with the addition of Scientific Reasoning and Technology (Britannica, 1992). The FOSS program is designed to be an independent science curriculum. However, many teachers who are bound by district curriculum adoption

policy to use other science programs choose to use FOSS as supplementary material.

The two most important goals of FOSS experiences are instructional efficiency and scientific literacy (Britannica, 1992, p. 8). Instructional efficiency refers to the ease of use for educators. The flexibility of the modular design allows FOSS to work in almost any curriculum, yet provide enough structure for even novice teachers to implement the activities successfully. To help the teacher implement the program, each module comes with a teacher preparation video that shows the activity in action and offers useful suggestions to teachers about materials, set up, and teaching strategies.

Scientific literacy, the second FOSS goal, refers to a set of experiences which are developmentally appropriate for young children, and which provide students with a foundation upon which more advanced scientific ideas can later be built (Britannica, 1992, p.8). FOSS accomplishes this task by matching developmentally appropriate activities with a hierarchy of science processes. This correlation is illustrated in a chart found in the introduction section of each of the module's teacher guides.

The FOSS program states two goals for culturally and linguistically diverse students: to make science accessible and meaningful for students from diverse cultures, and to

expose all students to the value of traditional ways that science has been used to solve problems in other cultures (Britannica, 1992). Teaching strategies recommended for English language learners include sheltered English (the use of gestures, slower speech and visual support), sensitivity to other cultures (consideration of issues such as personal interaction styles or differences in values or morals), and cultural enrichment (contributions by students from other cultures sharing their experiences).

As an elementary educator who has used FOSS modules to supplement my science program, I find the FOSS curriculum a superior teaching tool to have in the elementary classroom for a variety of reasons. First, the content of the FOSS modules is highly engaging both to my students and to myself. When content is interesting, it allows for a longer length of study, more in-depth investigations, and easier integration with whole language beliefs and teaching practices. Second, the organization of the FOSS curriculum, materials, and supplies makes it teacher-friendly. The teacher guides are easy to follow and complete. The guides contain the duplicating masters needed for all student worksheets. Third, each FOSS activity includes both a hands-on portion and a written or verbal assessment incorporating one of three types of assessment; reflective, pictorial, and hands-on. For students, the fact that the

lessons are active investigations which rely on group cooperation helps science to remain fun. Cooperative learning is encouraged in nearly every FOSS lesson. The active learning and student recordings make assessment and evaluation convenient, authentic, current, and insightful. Last, the FOSS science curriculum is based on current research about how children learn. The series was developed by Dr. Lawrence F. Lowery and his team of curriculum developers and researchers at the Lawrence Hall of Science, University of California, with grant money provided by the National Science Foundation.

Inadequacies of FOSS

Despite the many positive qualities that are inherent to FOSS, there is one aspect of the program which is inadequate. That gap is in the area of providing sufficient strategies and/or activities to support English language learners in their acquisition of English. For example, within the Models and Designs module, there are four different activities, each of which could involve two or more class periods to complete. However, for those activities there are only four brief suggestions for providing support for ESL students. Three activities contain a brief paragraph suggesting to the teacher that cultural differences might make some students uncomfortable in independent explorations. While this is accurate, it is

not explicit enough for teachers to know what changes they can make to improve the learning environment for students.

It is my belief that additional instructional and assessment strategies and activities relating to English language learners can improve the practicality of the FOSS program for many teachers who need more ideas and support for their non-English-speaking students. Specifically, the addition of strategies and activities which focus on cognitive academic language proficiency, and the use of dynamic assessment strategies would better meet the needs of English language learners. It is important that students gain an understanding of science concepts while at the same time increase their English proficiency and higher level cognitive abilities.

Science Processes

According to California's Science Framework (1990), science processes are systematic thinking skills which people use to make sense of the world around them. These processes help assign order and logic to environmental stimuli, and provide mental structures for input received. Whenever people are involved in experiencing and thinking about nature and scientific phenomena, planning ways to act on that knowledge, and thoughtfully explaining the results of their actions, the science processes are being used (Science Framework, 1990).

These tools for thinking were originally described in 1963 by Robert Gagné, a professor of Educational Psychology at the University of California, Berkeley. Based on Gagné's presentations and writings about the processes of science, an entire science program, Science-A Process Approach (S-APA), was developed in collaboration with the American Association for the Advancement of Science (AAAS). "The primary objective of each exercise throughout the sequence is to teach one or more of the processes of science" (AAAS, 1965, p. v).

A child's ability to use science processes is related to developmental growth, and should therefore be taught in a sequence from basic to complex. As Gagné explains, "if transferable intellectual processes are to be developed in the child for application to continued learning in sciences, these intellectual skills must be separately identified, and learned, and otherwise nurtured in a highly systematic manner" (1964, p. 4). Basic processes develop first through interactions with concepts which are visible, or concrete, such as the observation that some objects float in water, while other objects sink. More complex processes develop as students attain higher levels of understanding and abstract thinking. While the basic processes will be mastered before the more complex, students will often rely on basic skills when experiencing new or more abstract concepts. For

example, when students are involved in making inferences (a more abstract skill), they often rely on observations (a more basic skill). Therefore, basic processes are continually reinforced as more complex processes are introduced.

According to Gagné's hierarchy, there are 13 science processes which students need to develop. In contrast, California's Science Framework lists eight science processes. Both lists include the same eight processes; the difference lies in Gagné's additional five integrative processes. Careful examination of the skills and actions involved in each process suggest that those listed in the Science Framework are inclusive of Gagné's five integrative processes. Table 1 (p. 65) illustrates the parallels between the two lists of science processes, and the areas where the Science Framework list includes Gagné's processes.

The following descriptions of the eight basic science processes are presented in the order recommended for teaching as found in California's Science Framework (1990) which is consistent with the theory and practices described in Gagné's Science-A Process Approach. The eight basic process descriptions preceed Gagné's five integrative processes.

Observing

The most primary of the science process skills is observing. Students gather information by using one or more of their five senses. Only critical sensory attributes and concrete information are gained by observing. Students discover the color, shape, smell, or sound of an object or event. For example, students may use their sense of touch to discover that metal objects become warm when placed in the sun. Another time students might use observation is in watching and feeling what happens when two magnets are placed near each other.

Communicating

Communicating information once it has been gathered through observation is an important science process. This can be done by talking about observations and sharing information. Objects are named and described by the students. Another way of communicating is to act on information. Students might pull their hand quickly away from the hot metal slide, communicating to others that the object is hot to the touch. Communication can also take written form. This would include drawing pictures or graphic representations and writing words as a way to exchange ideas with other students.

Comparing

Assigning objects a one-to-one correspondence or comparing groups to find greater or lesser quantities is the next level of science processing. Objects and events are systematically examined in terms of similarities and differences. Measuring objects is a form of comparing. Students might compare the length of their pencil to the length of their paper using centimeters, a standard unit of measurement. The ability to quantify objects might take the form of actual counting; however, it might also be accomplished by estimating. In practice, students might be asked to guess how many jelly beans are in a jar, or they may need to estimate if the number of people in the room is less than 100.

Ordering

Ordering and organizing objects based on observations made at a prior setting includes the abilities to seriate (put in order), sequence, and group objects or events. For example, rocks might be ordered on a continuum from small to large or from rough to smooth. A more advanced application of organizing might be to label events on a time line according to chronological order.

Categorizing

Objects or events can be organized into groups by categorizing them according to a common characteristic or

attribute such as color or function. Once objects have been grouped logically, students can gain a better understanding of them. An example of useful categorization would be grouping animals according to their habitats in order to study adaptation. Animals which live in water would be placed in one group and animals which live in a forest would belong to a second group. Students would then be able to compare similarities and differences in feet, skin coverings, or body shape. Students might also group classroom objects according to their reaction to a magnet (one group of objects is attracted to a magnet, the other group is not). These objects would then be investigated to discover concepts of magnetism.

Relating

Relating two separate objects or events based on interactions between the two, or based on cause and effect relationships, is an advanced level of processing. This science process is cognitively demanding because it is not necessarily dependent on visible, concrete information. Relating might include the ability to use information gathered during prior observations and communications to determine that heat from the sun caused the metal object to become hot (cause and effect). Students move beyond the simple and begin to form hypotheses about relationships between two or more objects.

Inferring

Moving to the next level of processing, students will begin to see scientific patterns in objects or events by inferring connections between objects or events that are seemingly unrelated, and not necessarily observable. Students must be able to think more abstractly, not always relying on tangible objects or events. Inference involves students deciding if one event is the result of another. Students need to determine if something follows from something else; in other words, did the first event necessarily result in the second? Logical thinking patterns can lead students from something known (such as the movement of water in a fish tank) to a more removed concept (such as the movement of water in the ocean).

Inference is based on observations, communications, and organizations already accomplished. It requires more abstract thinking and logical reasoning skills than do the basic science processes. Students who have mastered the basic processes of communicating and inferring may be able to draw on those skills in order to understand and interpret data gathered during a scientific investigation.

Applying

Actually using scientific knowledge defines the process of applying. The application of prior understandings includes all other process skills at once. Students must be

developmentally capable of identifying attributes (observing), sequencing events (ordering), and identifying cause and effect relationships (relating) in order to use the knowledge gained in prior investigations. Application includes developing strategic plans and inventing new methods based on past experiences.

Controlling Variables

By controlling variables a student can "learn that he can make observations under conditions that he deliberately sets out to control and manipulate" (AAAS, 1965, p. 31). This kind of thinking develops from the student's ability to make accurate observations, define variables, and project outcomes. For example, students who are able to control variables might investigate the effect of thinner wire on an electric motor. The wire would be intentionally isolated as the variable of study based on observations of its purpose in the motor. Any resultant difference in performance of the motor would then be attributable to the change in wire.

Defining Operationally

Gagné explains defining operationally as being able to define terms "in such a way that another person can identify these events in terms of operations" (AAAS, 1965, p. 31). Within a scientific investigation, defining operationally is an application of the process of communicating because it involves the transfer of meaning between people. Students

must be able to define the terms they use in their investigation. If they are studying pets, they must clearly define what they consider a pet. Furthermore, defining operationally requires that the communication be clear and precise, rather than general and vague. For example, students are defining operationally if they are able to accurately communicate that an "axle" is "a shaft around which wheels revolve." Saying that an axle is "part of a car" would not be defining operationally.

Formulating Hypotheses

Science-A Process Approach uses the term "hypothesis" to mean a general statement (AAAS, 1965). Formulating hypotheses includes making statements such as "metal objects conduct heat." This statement would be based on observations, prior experiences, and predictions about the relationship and interaction of objects or events. It is the central topic or problem of an investigation.

Interpreting Data

Interpreting data "in ways which will at once get the most out of them, and at the same time avoid over-generalizing, is another important scientific activity" (AAAS, 1965, p. 32). Students should be able to infer conclusions based on data, as well as avoid arriving at conclusions which the data does not support. An example of interpreting data accurately would be when students count

and compare the number of metal rings picked up by electromagnets of varying strengths and conclude that the stronger the electromagnet, the greater the amount of metal rings which will be picked up. If students draw the conclusion that the number of metal rings picked up by the electromagnet increases because of where they were placed on the table, it would be obvious that these students are not interpreting data effectively.

Experimenting

Scientific experimenting involves formulating a problem, planning and executing a procedure, making observations, and drawing conclusions (AAAS, 1965, p. 32). It is a highly complex application of all science processes. It is an intentional combination of processes and skills, rather than a coincidental simultaneous occurrence. In other words in a truly scientific experiment, students purposefully set out to pose a meaningful question, decide which variables are relevant, and plan ways to isolate those variables in their investigation. They then make observations and gather data in order to arrive at conclusions which will answer their original question.

Within each of the science processes is an important function of language. Language is used to facilitate observations, generate comparisons, establish orders and categories, label relationships between objects, make

inferences, and apply science processes to actual investigations. Most importantly, language is a vital instrument for communicating about scientific knowledge. Language not only serves to facilitate science processes, but it also is an important result of the science processes. Accurate terms and labels can result from scientific investigations. They can represent ideas from quite simple to highly complex. Therefore, in addition to the science process skills, English language learners must also develop their language skills.

Cognitive Academic Language Proficiency

According to Cummins (1981), language development includes two separate sets of skills: Basic Interpersonal Communication Skills (BICS) and Cognitive Academic Language Proficiency (CALP).

BICS comprise the majority of everyday language use. They are the informal, personal manners of speaking and listening in conversations and social interactions. BICS is context-imbedded language, where meaning is actively negotiated and transmitted between the speaker and the listener (Cummins, 1981). Many gestures, facial expressions, and positional clues support the interaction. Cognitively, BICS is undemanding. The patterns and meanings of the language are fairly simple and easy to predict. An

example would be the task of determining whose turn is next during a game at recess.

CALP, on the other hand, is context-reduced language. Few, if any, linguistic or physical clues support the creation of meaning from language. CALP includes oral and written vocabulary which demands a higher level of cognitive functioning, related to literacy and academic achievement (Cummins, 1981). Reading a chapter in a history book is an example of CALP. CALP occurs in a more formal setting, involving higher levels of thinking and more abstract processing skills.

Achieving cognitive academic language proficiency is probably the most difficult mental process any person will ever master. There is often little support for the learner in this domain because academic language can be independent of context clues and methods of clarifying meaning. Yet, most of the formal educational experiences children encounter at school are in the CALP domain. Lessons in social studies and science include concepts, symbols, and language not used in any other setting. Literacy skills in these disciplines include decoding, comprehending, writing, vocabulary development, and more. Without a strong conceptual background in the students' primary language, and

equally strong modifications and support in English, this level of academic achievement will not be realized by many English language learners.

Cognitive academic language proficiency includes many skills and concepts in English, all of which are more cognitively demanding than BICS. The following descriptions will illustrate that students' understanding of vocabulary, word choice, formulaic language, and logical structures of English must be supported in order to insure their academic success.

Vocabulary

In order for students to develop cognitive academic language, they must have a strong understanding of key vocabulary. Increasing vocabulary knowledge will enable students to discuss concepts and ideas, expand their understanding of relationships between variables, and express their comprehension to others. Important terms need to be presented in a way which allows the learners to connect the words to ideas and concepts already known. Vocabulary words should be presented along with concepts and activities, rather than in list format separate from any relative context. Vocabulary might be developed by using terms in a rap song, or playing games which depend on the students' understanding of the terms. Once students have

gained appropriate vocabulary, they will be much more capable of expressing themselves in an intelligent, scholastic manner.

Word Choice

In conjunction with vocabulary development, students also need to learn skills in word choice. Knowing when to use key vocabulary is vital to being able to express oneself intelligently. Activities which encourage students to interact with each other offer many opportunities for English language learners to hear a variety of words and phrases used in context. Knowing when to say, "The tower was a tall pyramid shape," gives the student more credibility in exhibiting their knowledge than simply saying, "The tower was big."

Formulaic Language

Being able to understand phrases which carry their own meaning involves knowledge of formulaic language. For the elementary English language learner, a formulaic expression such as, "Hi, my name is Sam" might be used frequently at school. However, a more cognitively demanding use of language is needed in higher levels of learning such as science. For the fifth or sixth grade student, beginning a scientific report with the phrase, "Once upon a time" might be considered too juvenile, and inappropriate in context. Instead, the student should be taught to recognize formulaic

expressions, and judge when they are or are not appropriate to the setting.

Logical Structure and Format

Another essential aspect of CALP is the structure of language. Knowledge of the logical structure of language allows the student to access higher levels of thinking and communication. Students need to know, for example, that written work begins with an introduction or opening statement, presents the ideas in an orderly (often sequential) manner, and ends with a conclusion. When reading academic material, an understanding of this structure enables English language learners to focus on the meaningful cognitive aspects of the communication rather than on the language itself. The same structural understanding might then be applied by the learner when formatting papers to represent the logical structure of a class activity.

In conclusion, as English language learners increase their cognitive academic language proficiency they will rely on many higher level forms of thinking, such as relating and organizing the input they receive. High level thinking processes will be necessary for the academic growth of English language learners. These skills will, in turn, be further developed as they are used more during the process of learning. An example of one type of cognitive academic

language proficiency development program is the Cognitive Academic Language Learning Approach (CALLA).

Cognitive Academic Language Learning Approach

The purpose of CALLA is to assist English language learners in understanding and communicating within academic content areas, such as science. CALLA was designed by Chamot and O'Malley (1987) as a means of identifying the learning strategies of children. Chamot and O'Malley (1987) have organized learning strategies into three types: metacognitive, cognitive, and social-affective (See Table 2, p. 67).

CALLA's metacognitive strategies include previewing main concepts, identifying key ideas, pre-analysis of information, comprehension checks, planning, monitoring, and evaluating.

Cognitive strategies include using reference materials, taking notes, summarizing, inductive reasoning, inference, visual images, auditory representation, transfer, and grouping.

Social-affective strategies include asking for clarification, working cooperatively, self-talk to reduce anxiety, developing a sense of personal competency.

"CALLA is a framework for teaching academic language skills and learning strategies that can help an English language learner succeed in content areas. It is intended

to supply added support in English language development for ESL students, not to replace mainstream content instruction" (Díaz-Rico & Weed, 1995, p. 83). As students develop their proficiency with academic terms and concepts, they must also gain a means of communicating about those concepts to others.

Language Functions

Students will employ language both to increase and communicate their knowledge according to their needs. Language will vary according to the social situation, relationship of the people involved in the interaction, and purpose of the interaction. As children acquire a language they learn to manipulate aspects of language such as vocabulary or logical structure. In other words, they learn to use the "functions" of language. According to Halliday (1978), there are seven important functions of language (See Table 3, p. 68).

Instrumental

Language can direct or control the environment in order to cause something to happen. For example a child might say, "more milk," in an attempt to get her mother to bring her another drink. In the context of science, students use language to request needed supplies such as additional magnets or batteries.

Regulatory

Words can allow children to establish rules and boundaries. For example, when playing tetherball at recess one student yells at another, "No ropes!" During science activities students might be heard using regulatory language to direct another by suggesting, "I would do it this way...."

Representational

When students need to explain their understanding of a concept to a teacher, as in a reporting situation, they use the representational function of language. Words are arranged to represent thoughts and ideas. Language becomes the medium for displaying knowledge and conveying ideas to others. This function is crucial to success in the educational environment.

Interactional

As students work together they need to maintain a positive social connection. They use language to exchange ideas and responses in order to get along. Even simple exchanges of social etiquette such as "please" and "thank you" serve to create a positive connection between partners during lessons.

Personal

Language is also used to express emotions and needs. Students report sharing their school experiences with their family saying, "I made a motor today. I was a scientist!"

Heuristic

Words provide a means of finding out about the world. When students genuinely want to know about something, they formulate questions and use language to make sense of knowledge gained. In a science program, this function is involved when students hypothesize and analyze results.

Imaginative

Words and language can also be played with and enjoyed. When language is given an imaginative function students can explore their creativity and personal ideas. Word play can be an effective means of developing an understanding of how language works, as when students learn a new word and say it again and again just to hear the sound of it (try onomatopoeia!).

Cognitive Functions

In order to facilitate thinking and learning, educators must be able to identify the ways that students think (cognitive functions). When the mental processes of students can be identified, thinking can then be supported with specific instructional strategies. Research in the

areas of mental processes and thinking skills is thus an area of concern for all educators.

The work of psychologist and researcher Reuven Feuerstein (The Dynamic Assessment of Retarded Performers, 1979 and Instrumental Enrichment, 1980) is based on his belief that culturally disadvantaged individuals have cognitive potential that is undetected and not developed to its potential. Feuerstein worked with children who were refugees from displaced persons camps in the wake of the Second World War (Campione & Brown, 1990). Those children had obviously not had optimal formal learning experiences. Similarly, many of the children entering U.S. American schools have had little or no prior learning in their native language. Their resultant lack of academic skills and English proficiency renders them educationally disadvantaged.

Feuerstein (1980) has presented a "blueprint" of mental processing which he deems basic to learning. These functions do not necessarily appear automatically in students simply because they are learners. The cognitive functions must be directly taught, and should become an integral part of a curriculum. To this end, Feuerstein has developed the Instrumental Enrichment program (Feuerstein, 1980). Each instrument in this program "focuses on a specific cognitive deficiency but addresses itself to the

acquisition of many other prerequisites of learning as well" (Feuerstein, 1980, 125). Feuerstein (1980) has identified three phases in his cognitive functions blueprint: input, elaboration, and output (See Table 4, p. 69).

Input

In the first phase of information processing, input, students must gather all the information they need about a particular subject. Input includes using one's senses to gather information, using a system or plan to explore information, labeling and identifying information, using spatial and temporal referents, understanding laws of conservation, using multiple sources, and organizing an investigation. In the context of science, input roughly equates to preparations and exploratory activities. Each input function is now described according to Feuerstein's Instrumental Enrichment instruments.

Clear Perception

The ability to accurately see and relate to printed figures and images is clear perception. When students see two images and perceive one as being bigger than the other, it may be due to an error in perception caused by viewing the two images sequentially. In science, clear perception is important to making accurate observations and inferences.

Systematic Exploration

Systematic exploration permits students to gather an exhaustive collection of data from which they can make observations and comparisons. Without a pre-established method of gathering information, data may be incomplete or imprecise.

Labeling

Assigning names or descriptors to objects and events is labeling. In scientific investigations, students can use accurate labeling to provide precise information when communicating to others. For students to simply say that they "used the purple thing" is not accurate labeling. They must be given and taught to use correct terms and vocabulary for objects and events.

Temporal and Spatial Referents

Students need to be able to use temporal and spatial referents to organize input. Many science investigations include events which happen in a specific, chronological order. Temporal referents might include concepts such as first, second, third, or before, next, and last. Spatial referents such as positional phrases (in the corner, next to, to the left of, etc.) and physical descriptions (round, flat, triangular, etc.) will allow students to determine an object's position in space and communicate that position accurately to others.

Conservation, Constancy, and Object Permanence

Conservation, constancy and object permanence require students to identify characteristics and attributes of an object that remain unchanged no matter how the object is manipulated or arranged in space. For example, a triangle is still a three-sided closed figure regardless of how it is turned by students.

Using Two Sources of Information

When students are using two sources of information they are gathering more precise data. Students might make observations of the attributes of an object based on their senses (a primary source), and then combine that information with observations about the object's functions (a secondary source). Another method of using more than one source is when students read about an event from a science text (their first source of information) and then see the event happen themselves in an in-class investigation (their second source).

Need for Precision

Precision is important in the observation and perception of attributes of objects. The shape, color, texture, or weight of an object must be carefully and accurately determined. Choosing a wire that is "almost" the same size as others used in an investigation could result in faulty information and inaccurate conclusions.

Elaboration

Once information has been gathered, it is ready to be processed. Feuerstein refers to the second phase of cognitive functions as elaboration. These processes move from initial preparations to final evaluations. This is somewhat like finally getting to eat the meal which has taken hours to prepare. The following elaboration functions are described according to the instruments of Feuerstein's Instrumental Enrichment (1980).

Relevance

Relevance is determined by the goals of students' investigations. When students are examining similarities between rocks, they might determine that the location of the rock is irrelevant to its similarity in size, shape, or color to other rocks.

Interiorization

Interiorization refers to the capacity to create individual, internal representations of objects, events, or concepts. For example, if students are capable of planning the procedures to their investigations in science, then they can be said to have interiorized representation of time and sequence. They have an internal understanding and mental representation for concepts such as "yesterday," "today," and "tomorrow."

Planning Behavior

Planning involves not only setting goals, but also determining the steps needed to reach those goals. Students must plan the steps of their scientific experiment with detail, sequence, logical order, and relevance. Planning includes predicting outcomes, comparing possible sequences, and avoiding impulsive behavior.

Broadening Our Mental Field

When students can attend to more than one source of information they are broadening their mental field. They are increasing the amount of information they can process along with increasing their capability to consider many aspects of single objects in order to make comparisons or see relations between objects. An example of broadening one's mental field in science is when students apply their memories of prior investigations with magnets to their current work in developing a working electromagnet. This requires them to maintain focus on their current task, while relating and combining information from past experiences.

Projecting Relationships

Students who are capable of projecting relationships can establish relations between objects or events, and apply that knowledge to new situations. For example, students who have established the understanding that light affects the growth of plants should be able to project, or apply, that

knowledge to the problem of finding a location for planting their garden.

Comparative Behavior

Identifying the similarities and differences between two objects involves comparative behavior. Students who compare attributes of objects must rely on accurate and precise observations and perceptions. If students are comparing the attributes of two types of fish, they must find similarities and differences in details about the fish, such as the type of food they eat or the size and shape of their bodies.

Categorization

Grouping objects or events according to attributes or characteristics is categorization. Sets can be formed on the basis of commonalities between objects, such as including rain, snow, heat, and wind in the category of weather because they all are types of conditions of the air in the atmosphere.

Hypothetical Thinking

Hypothetical thinking refers to the ability to judge relations between objects and predict possible outcomes of acting on that object. For example, students use hypothetical thinking when they mentally imagine what will happen if they put the ice cube in the tub of hot water. This type of thinking relies on other functions including

clear perception, projecting relations, and broadening our mental field.

Logical Evidence

Logical evidence is an important part of a valid scientific investigation. When students reason based on clear perceptions, accurate and precise information, and established relationships between objects, they can arrive at valid inferences and conclusions.

Output

The third and final phase of Feuerstein's cognitive functions is output. Output is the expression of the solution to a problem. Students must use clear, precise language to be sure that they have accurately communicated their findings. Output may take the form of oral or written communication. The descriptions of these output functions which follow are in accordance with Feuerstein's Instrumental Enrichment (1980) instruments.

Overcoming Egocentric Communication

When communicating information to a partner in a scientific investigation, students need to overcome egocentric communication. Descriptions must be explicit and precise enough for others to follow their thought process. If students are explaining how they arrived at their conclusions, they must explain each step as if the listener does not know the subject matter. Students must not assume

that because they understand their reasoning, others will also.

Overcoming Trial and Error

By taking time to formulate a hypothesis and think about the possible results before actually performing the experiment, students can overcome trial and error behaviors. This type of self-control and structured investigation is cognitively demanding. Students must resist the impulse to begin exploring without first establishing a procedure that will allow them to organize their investigation. Little valuable information can be gained by random or hasty investigation procedures.

Restraining Impulsive Behavior

Students need to remember that restraining impulsive behavior can help them attain better thinking habits. When students are able to remind themselves to "wait a moment and think" they might avoid coming to inaccurate conclusions based on hasty generalizations. Planning the steps of a science investigation, and following the plan, will assist students in operating without impulsivity.

Overcoming Blocking

By overcoming blocking students can remain open to new situations or activities. For many children, the result of past failures is a negative attitude toward new experiences. This may be specific to the activity which resulted in their

perceived failure, or it may be a more generalized reaction to any new or unfamiliar experience. In science investigations, much is unknown. Students must work to remain open to new experiences, and willing to accept their mistakes.

Critical Thinking

Once educators understand how students process information they can then begin to apply that knowledge to helping students become better thinkers. Educators need to develop strategies for teaching children how to think clearly and how to increase their thinking capabilities. Robert Ennis defines critical thinking as "reasonable reflective thinking that is focused on deciding what to believe or do" (1987, p. 10). Both dispositions and abilities are considered significant features of Ennis' critical thinking theory (See Table 5, p. 70).

Dispositions are those mental qualities and attitudes which serve to increase one's thinking capacity. Fourteen dispositions are recorded by Ennis. They include seeking a clear statement of the problem, taking into account the total situation, being open-minded, and seeking as much precision as the situation permits (Ennis, 1987, p. 12).

Ennis also specifies twelve critical thinking abilities. Abilities as defined by Ennis are those competencies and skills necessary for thought beyond a rote

memory level. These abilities are listed (and Ennis suggests that they be taught) in a hierarchic order from simple to more complex. Specifically, Ennis enumerates four areas of critical thinking ability: clarity, basis, inference, and interaction (1987, p.16). The first of these abilities is clarity.

Clarity

Clarity includes focusing on a question, analyzing arguments, asking questions, defining terms, and identifying assumptions (Ennis, 1987, p. 17). Focusing on a question means identifying a problem or hypothesis which can be solved through critical thought and investigation, such as "What effect does heat have on water?"

Analyzing arguments is a way of clarifying arguments or statements made in support of an answer to the question being posed. For science students this means thinking critically about information presented as being able to answer the key question. Students might ask themselves, "Is it true that heat always changes water? How do I know? Is any information I have irrelevant to the investigation, or in conflict with my question?" This line of thinking leads directly into the next area of clarity; asking questions.

Students must be able to formulate questions which will provide them with more information about their hypothesis. For example, they might ask, "What is meant by heat?" On

the other hand, students must also be able to answer questions asked of them, such as, "What would be an example of heat changing water?"

Defining terms is a more advanced level of clarity. Without an adequate understanding of the terms used in science, students are not likely to master the necessary science processes, or think critically about scientific investigations. Critical thinking relies on clear, understandable, agreed-upon definitions of terms in order for scientific investigations to be considered valid and replicable. If students are not sure about what "change in water" really means, then they will not be able to identify it when it happens.

The last area of clarity is identifying assumptions. Like defining terms, this area is a more advanced level of critical thinking. Students need to be able to recognize statements made which are believed to be true, but are not proven so. An example of this is when students say that the water they are using was dirty because it left residue on their equipment. They are assuming (not proving) that the residue was from dirt particles in the water, rather than the more likely reality that the residue was from the mineral content of the water.

Basis

The second major area of critical thinking ability is basis. In order to think critically, students must have a solid basis for their thoughts. Basis includes judging the credibility of a source and observing.

"Since a large share of what we come to believe has other people as its source, the ability to judge the credibility of a source is crucial" (Ennis, 1987, p. 19). Students need to be taught to consider such aspects as level of expertise and reputation when determining if a source is credible. For example, students should acknowledge a difference in level of expertise when hearing information from a friend as opposed to gaining information from a research scientist. Obviously, the researcher has a higher level of expertise, and therefore, has greater credibility as a source of information. Similarly, students should realize that a current year encyclopedia will contain more credible data about space exploration than would a 1965 version of the same encyclopedia series.

Observing is also vital to critical thinking. Students need to be taught to observe, rather than simply watch. The difference lies in the focus of observations on variables and predicted outcomes, and the intentionality of observing in order to collect data. Merely watching water boil does

not provide adequate information on which students can base inferences and conclusions.

Inference

Inference is the third part of critical thinking abilities. Ennis describes three types of inference: deductive, inductive, and value judgments. "Basically, deduction is concerned with whether something follows necessarily from something else" (1987, p. 20). For example, students investigating the effect of heat on water might say that since the heat made the water warm, if the heat were removed, then the water would cool. This type of thinking moves from the more general (changes caused by heat) to the more specific (effects of heat on water).

Induction moves in the opposite direction. Students make generalizations based on reasoning from the specific details. An example of inductive thought is that because heat made the water in the pan become warmer (specific), heat from the sun would cause the water in a lake to become warmer (general).

The last type of inference is value judgment. When students base their thinking on past experiences, possible alternatives, and consequences of their actions they are making value judgments. Students whose assignment is to dissect a frog must weigh their personal beliefs regarding the importance of the frog's life against their

understanding of the possible consequences of the dissection. They must consider any viable alternatives to killing the frog, and, if there are any, they must decide whether or not to employ them (for example, there are now computer programs available which imitate such a dissection.)

Strategies and Tactics

The fourth significant area of critical thinking according to Ennis involves the strategies and tactics of deciding on an action and interacting with others. Deciding on an action requires that students have defined the problem, selected appropriate criteria to judge solutions, formulated alternative solutions, made tentative decisions about what to do, and followed through with their decision (Ennis, 1987, p. 15). This is seen in student investigations when students must decide when to conclude their study. They must have a clear understanding of the questions they have posed; they must have some predictions about what will possibly occur; they must know what to look for to indicate that their question has been answered; they must have arrived at some prior agreement about what will constitute a completed investigation; and they must be able to stop once they have determined that it is appropriate to do so. Clearly, deciding on an action involves integrating (combining) most of the subordinate aspects of critical

thinking already described. These factors must be synthesized by students, integrated and appropriately applied. Similarly, interacting with others is an integrative task.

"Interacting with others in discussions, presentations, debates, and written pieces is crucial for critical thinkers" (Ennis, 1987, p. 23). When students defend their procedures or summarize their findings in group discussions, they are interacting as critical thinkers. They must clearly state their findings, or offer further information for clarity when others request it. They must show logical processes of observations and data collection on which they base their inferences and conclusions. They are applying all three critical thinking abilities; clarity, basis, and inference at once, in an integrated manner.

Although critical thinking dispositions and abilities are presented separately, they are in practice, interactive. "The actual practice of critical thinking...requires us to combine these abilities and to employ them in conjunction with the critical thinking dispositions and knowledge of the topic" (Ennis, 1987, p. 24). Students must be able to seek a clear statement of the problem, and try to be well informed by asking for clarification when needed. They should use inductive reasoning to arrive at conclusions

based on the observations and criteria of their investigation.

Triarchic Theory of Intelligence

Ennis is not alone in his belief that critical thinking and reasoning involve many levels of intellect. Robert Sternberg (1985) presents a triarchic theory of intelligence. This theory contains important parallels to both Ennis' critical thinking and Feuerstein's cognitive functions. Sternberg examines intelligence in terms of the inner world of the person (the internal thought processes which allow the individual to perform intelligently), the external world of the person (the environmental and cultural contexts in which intelligence occurs), and the experiences of the person (the interactions between the individual and the world).

Of primary importance are the internal cognitive processes involved in intelligent thought. Sternberg (1985) labels these as information-processing components, and he lists three, classified by function: metacomponents, performance components, and knowledge-acquisition components (See Table 6, p. 72).

Metacomponents

Metacomponents are "executive processes used to plan, monitor, and evaluate one's strategy for solving problems" (Sternberg, 1987, p. 198). The seven metacomponents

include; decision as to just what the problem is that needs to be solved, selection of lower-order components, selection of one or more representations or organizations for information, selection of a strategy for combining lower-order components, decision regarding allocation of attentional resources, solution monitoring, and sensitivity to external feedback.

In a science investigation, students would need to be sure they understand the problem. To do this they might read the problem aloud to themselves and then try to rephrase it in their own words or rephrase it to a partner. Another metacomponent process is creating a simple list of words that serve to clarify the problem for the students and assist them in their thinking. For example, if students were to investigate the effect of light on plant growth, listing the words "direct sun, indirect sun, light bulbs, 60 watt, 100 watt, fluorescent, and colored" might help students expand the possible variables rather than limit themselves to the initial reaction that the problem is referring to sunlight only.

Performance Components

The second part of Sternberg's theory is performance components. These are "nonexecutive processes used to execute the instructions of the metacomponent for solving problems" (1987, p. 198). This stage involves the

implementation of the plans which were made by metacomponents. In other words, performance components actually carry out the students' thinking.

While there are many possible performance components, there are only three which Sternberg has identified as being important to intellectual functioning; encoding components, combination and comparison components, and response components. Encoding components involves inferring relations between stimuli, or finding valid relationships between two or more aspects of the data. For example, students might say that because the ground outside is wet everywhere, it must have rained last night. This is one fairly obvious explanation, but students must also be aware that there are other viable interpretations. Students must also become aware of inferential fallacies such as drawing conclusions which have little or nothing to do with the data (irrelevant conclusions) or making assumptions that what is true of exceptional cases is also true of typical cases (hasty generalizations).

Another important performance component is the combination and comparison component. Students do this when they use analogies such as "this lever we made with our ruler is like the teeter-totter we have on our playground. If this lever can lift little weights, then I bet our teeter-totter can lift a lot of weight."

A third performance component is the response component (Sternberg, 1985, p. 106), or mapping higher order relations between relations. This is the idea that students can infer possibilities beyond the strict evidence of a series of events or observations. An example of this is when students notice that each time the wind blows there is static electricity in their hair. They might then project this inferred relationship between wind and static electricity and use a hair dryer to attempt to create the same results. They infer the unknown information by extending that which they already know.

Knowledge-Acquisition Components

The third part of Sternberg's triarchic theory is knowledge-acquisition components, or learning processes. These are "nonexecutive processes used to learn how to solve the problems in the first place" (1987, p. 198). As described by Sternberg (1985, p. 107) the knowledge-acquisition components are; selective encoding, selective combination, and selective comparison. These components include not only the acquisition of knowledge, but also the acquisition of vocabulary.

Sternberg explains that there are three important ingredients involved in learning vocabulary (1987, p. 204). First, students must be able to figure out meanings of words from context. The context might be a reading passage, or it

could include a scientific investigation which would introduce new vocabulary to the students. Second, students must pay attention to the kinds of information to which they can apply their linguistic skills. For example, in trying to figure out the meaning of "friction" students must determine if the new vocabulary word is applicable in all science investigations they are involved with, or if the word applies only to some of these settings. Using setting cues (time, place, situations) students can gain information about the generalizability of the new word. The third ingredient important to learning vocabulary is the mediating variables that affect how easily the students can relate the new word to context cues. An example of a mediating variable is the number of contexts in which students are exposed to the new term. If students hear the word "friction" used in reading passages, scientific investigations, and references to playground settings, then their understanding of the term will be greatly enhanced.

As Sternberg points out, the three components of his triarchic theory are highly interactive. The metacomponents can be seen as the coaches on a baseball team. They tell the members of the team (the performance and knowledge-acquisition components) where to play and how to act. The team members in turn relay information back to the coach about how the game is proceeding. The coach then takes this

information and makes changes in player positions or adjustments to the batting order. "An important part of metacomponential functioning is figuring out exactly what changes need to be made when, and how these changes should be implemented" (Sternberg, 1987, p. 198). In order for students to become better all-around thinkers, they must be trained in all three componential skills. They must be shown how their metacomponents control and evaluate their performance and knowledge-acquisition components. Students must understand that the metacomponents enable them to justify why they do certain things, rather than just performing without reason. Students must also be shown that their performance components are important because they allow for action on what the metacomponents plan. In other words, students need to see that planning is of little value without action. Finally, students should realize that without their ability to learn (knowledge-acquisition component) they would not be able to do much of what they do everyday, such as read a book.

Assessment

Testing and assessing student learning is an essential part of the educational process. Students' achievement, level of current understanding, and/or informational gaps prior to instruction can be measured by assessing their knowledge and ability levels. Growth can then be determined

by finding the difference in student performance over time. Ideally, assessment results are then used to help determine curriculum and instructional methods. But which method of assessing students' performance and learning is best for English language learners in science?

Many educators believe that traditional testing procedures do not produce the most desirable results for learners when compared to the interactive style of the dynamic assessment approach.

Standardized Testing

Traditionally, students have been tested using a standardized "static" test. In standardized "static" tests, students are required to work alone to answer questions and solve problems in specific curricular areas. Most standardized tests are timed, allowing an allotted period for students to respond to all the test items. Test administrators (often not the students' teacher) are careful not to intervene with the students at any time during the testing. The testing environment is quiet and sterile. Should students encounter difficulty understanding the questions, or need assistance in any other way, they are denied such assistance and must proceed without any help. No student-student or student-teacher interaction is allowed. The students' work is scored and the scores are then tabulated and quantified, usually in a percentile

rating. Scores are typically sent home to parents in a written communication, often with little or no explanation of the testing material.

These scores are said to be representative of students' independent performance abilities. These static test scores are considered to be valid measures of students' abilities, only when all students have had "equivalent opportunities to acquire the knowledge or routines being evaluated" (Campione & Brown, 1990). However, as Campione & Brown point out, the above assumption of test validity does not apply to students in California classrooms who are diverse in culture, language, and educational background. Lack of proficiency in English puts the learner at an immediate disadvantage in a static testing situation. If students have any special circumstances, such as not being fully proficient in English, then the static testing procedures would represent a huge omission of students' learning potentials. For example, an English language learner who has performed successfully in a supportive classroom environment might not be able to explain the concept of "buoyancy" on a written test due to lack of vocabulary and/or literacy skills (not due to a lack of knowledge or understanding, as might have been assumed according to static test measures).

Most educators have experienced standardized tests as

described above. Most would argue that the tests are not representative of what students are capable of, nor do they accurately measure the students' current level of classroom performance. In light of the increasing dissatisfaction with static standardized testing procedures, a radical change is beginning to take place in the field of assessment, in favor of utilizing dynamic assessment techniques.

Dynamic Assessment

Dynamic assessment has been defined as assessment which occurs "while learners are in the process of solving problems, rather than after they have completed a problem" (Lajoie & Lesgold, 1992). This definition of assessment implies student/teacher interactions during the testing process, as opposed to the traditional testing environment of silence and independence on the part of the student. As Hickson & Skuy (1990) explain, "The most significant part of a mediated learning experience is not the language or the content of the activity, but the process of mediation by the adult." This implies an ongoing interaction between the facilitator and the child, so that problem-solving behavior can be assessed as it occurs. This represents a significant change in the assessment paradigm. However, dynamic assessment should not be seen as a replacement for standardized tests, but viewed as an additional method of

providing teachers with information which is not available through traditional static measures.

Dynamic assessment stems from the work of Feuerstein and Vygotsky. For both researchers, motivation in finding alternative assessment methods came from working with children who were not provided adequate learning experiences (Campione & Brown, 1990). These researchers agreed on the idea that even among intellectually retarded children there were those whose learning potential was unidentified. Thus, they each formulated theories and strategies designed to increase thinking skills in children.

Children who are linguistically or culturally disadvantaged frequently have not had learning experiences which prepare them for academic success in U.S. American schools. "They are arriving at school with the strengths of their own culture but without many of the pre-school experiences that prepare children for the typical curriculum" (Cohen, 1994). They may lack the experience of having been read quality children's literature, which is generally acknowledged in the field of education as being a vital step in early literacy skills. They may also lack the ability to get along with others, or the ability to maintain mental focus on a task long enough to benefit from it academically. These students are often labeled "at-risk" because of limited skills in English, low academic

achievement, and high drop-out rates (Carter & Wilson, 1992).

In the case of the English language learner, differences in language and/or culture often render the child at a disadvantage in an assessment situation. "Both the testing situation and the test content may be rife with difficulties and bias for language minority students" (Diaz-Rico & Weed, 1995, p. 187). Such differences would prevent many children from performing on standardized tests at a level truly indicative of their knowledge and potential. "The central premise of dynamic assessment is then that disadvantaged children have an intelligence potential identical to that of other groups" (Kaniel & Reichenberg, 1990). The supportive testing environment provided by genuine interactions between tester and student is what allows dynamic assessment to be both trustworthy and fair for children who are culturally or linguistically different.

Using dynamic assessment, students are no longer required to work alone in a testing situation. For students, this form of assessment becomes an interactive, rather than an isolated activity. They would be seated near the teacher, and assured that the teacher is available for help. During a dynamic assessment session, the tester would incorporate test-relevant skills such as re-reading the question or explaining it to the student to insure student

comprehension of the task (Day & Hall, 1987). When assistance is needed, students may appeal to the teacher and receive hints, suggestions, and other forms of feedback. The teacher would provide such support without giving the student the solution and negating the trustworthiness of the assessment itself. In fact, a student's appeal for hints can provide valuable diagnostic information to the teacher regarding possible weaknesses in cognitive functioning or critical thinking abilities. This active exchange of ideas and suggestions is thoroughly different from the static tests to which most students and educators are accustomed.

For educators, assessment becomes an interactive event, rather than a tense period of waiting for results. The tester "is transformed from an objective spectator into an active spectator who directs the child to the underlying thought principles in the test's assignments" (Kaniel & Reichenberg, 1990). The educator then gains a measure of what students are capable of doing with support, as compared to what the students are capable of independently. As defined by Vygotsky (1978) the zone of proximal development is "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers." For English language learners, adult support would

increase students' comprehension by eliminating any possible confusion caused by language differences. Students working in their zones of proximal development would gain a more complete understanding of tasks and content, allowing them to acquire both proficiency in English as well as cognitive academic learning.

Dynamic assessment is also a method of monitoring learning as it takes place. The assessor can diagnose and improve the learning situation as the testing proceeds. "The utility of dynamic assessment is that immediate feedback can be provided to the learners while they are in the process of solving problems, when and where they need assistance" (Lajoie & Lesgold, 1992). With such direct and immediate diagnoses, educators can gain important insights into student thinking and processing skills, and develop more detailed portfolios of student growth and abilities over time.

Several researchers have studied the differences between standardized "static" tests and informal dynamic assessments among groups of learning-disabled children (Hall & Day, 1984; Campione & Brown, 1984). Findings indicate that dynamic assessment can provide educators with a method of discerning differences in the cognitive abilities of students. Perhaps the most significant change educators can make is the realization that when students are deficient,

the assumption should not be that the student has failed to learn, but rather that the instructional techniques have not been successful in teaching the child (Lidz, 1987). As Lidz further explains, dynamic assessment "is a general concept rather than a specific set of tasks and procedures, and that initial data suggest that the concept has a great deal of potential." While more research is needed, the potential of dynamic assessment procedures in mainstream classroom settings for learners who are culturally, linguistically, or otherwise diverse from the mainstream student population appears promising.

Table 1

Comparison of Science Processes

Science Framework(1990)	Gagne [S-APA] (1964)	Descriptors
Observing	Observing	Using senses to gather data
Communicating	Communicating	Exchanging information with others
Comparing	Comparing	Assigning correspondence or quantity
Ordering	Ordering	Sequencing or seriating
Categorizing	Categorizing	Grouping by attributes
Relating	Relating	Finding cause and effect relationships
Inferring	Inferring	Making conclusions by reasoning
Applying	Applying	Using prior knowledge in new situations. Includes use of all subordinate processes

(table continues)

Science Framework (1990)	Gagne [S-APA] (1964)	Descriptors
	Controlling variables	Isolating critical features
	Defining operationally	Assigning meanings of key terms in investigation
	Formulating hypotheses	Guessing about relations between variables
	Interpreting data	Making logical inferences and conclusions based on data
	Experimenting	Combining all processes to test hypotheses

Table 2: Cognitive Academic Language Learning Approach (CALLA) (Chamot & O'Malley, 1987)

Metacognitive Strategies

- Previewing main concepts
- Identifying key ideas
- Pre-analysis of information
- Comprehension checks
- Planning
- Monitoring
- Evaluating

Cognitive Strategies

- Using reference materials
- Taking notes
- Summarizing
- Inductive reasoning
- Inference
- Visual images
- Auditory representation
- Transfer
- Grouping

Social-Affective Strategies

- Asking for clarification
- Working cooperatively
- Self-talk to reduce anxiety
- Developing a sense of personal competency

Table 3: Language Functions (Halliday, 1978)

Instrumental
Regulatory
Representational
Interactional
Personal
Heuristic
Imaginative

Table 4: Cognitive Functions (Feuerstein, 1980)

Input

- Clear Perception
- Systematic Exploration
- Labeling
- Temporal and Spatial Referents
- Conservation, Constancy, and Object Permanence
- Using Two Sources of Information
- Need for Precision

Elaboration

- Relevance
- Interiorization
- Planning Behavior
- Broadening Our Mental Field
- Projecting Relationships
- Comparative Behavior
- Categorization
- Hypothetical Thinking
- Logical Evidence

Output

- Overcoming Egocentric Communication
- Overcoming Trial and Error
- Restraining Impulsive Behavior
- Overcoming Blocking

Table 5: Critical Thinking (Ennis, 1987)

Dispositions

- Seek a clear statement of the thesis or question
- Seek reasons
- Try to be well informed
- Use and mention credible sources
- Take into account the total situation
- Try to remain relevant to the main point
- Keep in mind the original and/or basic concern
- Look for alternatives
- Be open-minded
- Take a position
- Seek as much precision as the subject permits
- Deal in an orderly manner with the parts of a complex whole
- Use one's critical thinking abilities
- Be sensitive to the feelings, level of knowledge, and degree of sophistication of others

Table 5 (continued) Critical Thinking (Ennis, 1987)

- Abilities
  - Clarity
    - Focusing on a question
    - Analyzing arguments
    - Asking and answering questions of clarification and/or challenge
    - Defining terms, and judging definitions in three dimensions
    - Identifying assumptions
  - Basis
    - Judging the credibility of a source
    - Observing and judging observation reports; criteria
  - Inference
    - Deducing and judging deductions
    - Inducing and judging inductions
    - Making value judgments
  - Strategy and Tactics
    - Deciding on an action
    - Interacting with others

Table 6: Triarchic Theory: Information Processing Components (Sternberg, 1987)

- Metacomponents
  - Decision as to just what the problem is that needs to be solved
  - Selection of lower-order components
  - Selection of one or more representations or organizations for information
- Selection of a strategy for combining lower-order components
  - Decision regarding allocation of attentional resources
  - Solution Monitoring
  - Sensitivity to external feedback
- Performance Components
  - Encoding components
  - Combination and comparison components
  - Response component
- Knowledge-Acquisition Components
  - Selective encoding
  - Selective combination
  - Selective comparison

CHAPTER THREE: THEORETICAL FRAMEWORK

Based on the findings of the literature review, I will now present a theoretical framework for the teacher's resource guide. The following descriptors are a synthesis of AAAS' science processes, Cummins' cognitive academic language proficiency, CALLA's language learning strategies, Feuerstein's Instrumental Enrichment cognitive functions, Ennis' critical thinking dispositions and abilities, and Sternberg's triarchic theory. The synthesis is an attempt to list a minimum number of functions that contains an inclusive description of the many areas of overlap between the above theories. If these theories are to be of practical value, educators need a unified view of cognitive functioning and thinking processes.

In order to arrive at a synthesis of the above theories, functions were compared, parallels were identified, and a composite description was formulated. The descriptions were then relabeled when necessary for clarity, grouped, and listed in a logical format (modeled after Feuerstein's cognitive functions) to include exploration, elaboration, and extension. This integrated cognitive functions list was implemented in an after-school science program which will be described in greater detail in Chapter Four.

Exploration

This first set of functions, exploration, refers to thinking processes which help students focus on the problem at hand, prepare mentally for scientific investigations, organize their observations, and gather relevant information.

Openness

In order to gain information about something, students must be willing to explore new ideas; they must have openness toward scientific explorations. They must have some sense of adventure, showing an ability to take small risks and try new things. Students who will not touch materials prepared for a science lesson have little or no openness toward science.

Focus

Students must be able and willing to focus on the task at hand. They must be able to maintain their attention on the task or object of investigation long enough to gain information from it. This often happens naturally when the activity is presented in an exciting manner, drawing students in by appealing to their natural curiosity. Students who are focused are involved in the activity, and maintain their attention without reverting to visiting with others or playing with materials.

Pre-analysis

Pre-analysis, or looking ahead to find the critical aspects of a problem, helps students determine possible solutions. Once the problem has been analyzed, then it can more easily be solved. If students were to jump into a problem situation with no pre-analysis, their actions would be random and largely inefficient.

Multiple Sourcing

When students can use multiple sourcing, they are able to consider two or more attributes at the same time. There is an ability to use more abstract thinking, not limiting themselves to single characteristics of objects. For example, students who realize that friction is a combination of both texture and movement are able to use multiple sourcing.

Spatial

Spatial awareness, or understanding the importance of where an event occurs, is critical to understanding the event itself. For example, students need to be aware that their compass reacted wildly only when they walked past the computer. When students can describe physical location, proximity, and spatial orientation, they have displayed spatial skills.

Temporal

Time cues and sequences of events comprise the temporal function. Students must be able to explain and express when an event happened. This would include not only the time of occurrence, but also the length of time, or duration, of an event.

Symbolization

By representing objects or events with symbols, the symbolization function, students will be better able to internalize information, processing it enough to develop a symbol for it, or relate it to a known symbol. Symbolization also benefits students who may have difficulty with written language. It is similar to pictorial representation and would allow students whose written skills were weak to be able to label and express knowledge.

Organized Investigation

An experience which is organized in a systematic way shows organized investigation. Students should be capable of developing a plan, following procedures, or searching systematically. This allows them to complete a thorough investigation, with less chance of missing key features.

Information Input

When students gather data accurately and with credibility, they are gaining information input that they can use to solve the problem. They must input, or collect,

information selectively, attending only to those pieces of information which are relevant and productive to their investigation. Students must use careful methods of gathering data so that they do not make faulty conclusions.

Selective Reception

When students are able to determine the critical attributes of a problem, without being distracted by irrelevant information, they have displayed selective reception. An example of this would be realizing that the color of a wheel has nothing to do with how well it rolls.

Labeling

Labeling information and elements by giving them a name will enable students to more accurately remember events and objects observed. The act of labeling also allows students to express this information both in discussion and in writing to others.

Semantic/lexic

Students' ability to define vocabulary, ideas, or messages clearly depends on their ability to use semantic clues. The ability to express meaning with accuracy is clearly vital to communication.

Elaboration

This second set of functions, elaboration, refers to thinking processes which students use to actually perform scientific investigations. They are presented in

approximately the same order that they are used during science activities.

Problem Definition

Problem definition means that the problem or challenge must be clearly defined in terms of what students are being asked to do. The expectations should be made explicit, and explained until all students understand their task. Students should be willing and able to request clarification if they are not fully ready to begin.

Working Memory

Students who have the capacity to remain cognizant of more than one attribute while working on a problem have a strong working memory. The various bits of information needed must be kept in mind. For example, students should be able to keep shape, size, and weight in mind simultaneously while attempting to create a go-cart which will travel two meters.

Maintaining Mentation

While working, students must be capable of fending off interruptions to their thought processes, or maintaining mentation. They must maintain their attention and focus on the work, and not let other students or peripheral noise cause interference with their thinking.

Expansion

Expansion is the ability to build on thoughts and ideas, allowing other similar experiences to be related to the current problem. It means that students can begin with an idea and gradually add to it, change it, delete portions of it, etc. The use of a paper clip to connect two straws might lead to the expanded notion of using metal bars to connect wall beams in a house.

Flexibility

"Well, that didn't work. I'll try it another way," is demonstrative of flexibility. Thought processes must remain fluid enough to entertain more than one idea. Problems must often be viewed from a variety of vantage points, rather than limiting the view to a single concept.

Metaphorical Thinking

When using metaphorical thinking, students are able to apply something they already know to that which they are learning. Likenesses, similarities, and correlations all help students to relate old information to that which is new. When describing snow to someone who has never seen it before, students might make connections to some of what they know about ice and frost in their refrigerator's freezer.

Comparison

Finding the similarities and differences between objects or events involves comparison. When comparing the

relation of attributes or characteristics, students can gain valuable information and understanding.

Categorization

Categorization refers to attempting to find the group or category to which an event or object belongs. Categories are based on observable and verifiable attributes. Membership in a category means that the object or event has enough similar characteristics as to be tied to the other members of the group. Students must be capable of determining categories, sets, and experiences and then placing new information in them.

Logic

When students can defend their thoughts and actions with reasons, they are using logic. When problems are approached randomly, with no apparent planning or strategy, connections vital to their understanding may be missed. They simply need to be able to present an explanation of their thinking so that they (and others) can become aware of the thought processes which led to their findings.

Summary

As in literacy, summary refers to finding the main ideas or concepts. When students are involved in learning about weather, for example, they need to be able to tease out the important information and understand the "big ideas," like the concept that air is constantly moving.

When students get too concerned with details they may lose sight of the intended learning.

Planning

In order for the testing of hypotheses to be valid, planning the procedure is vital. Random activity will not produce valid results. The plan must include sequential actions and logical reactions.

Formulating Hypotheses

Students must be willing to take chances and guess about possible solutions and relations between objects by formulating hypotheses. Students who are not risk-takers will find hypothesizing extremely uncomfortable, if not hopeless. Hypothetical thinking means considering different possibilities or guessing about and changing relationships between objects.

Testing Hypotheses

In testing hypotheses, students are involved in the very heart of scientific thought. A specific, planned procedure is implemented in order to gain information and results to a certain set of circumstances. The results of the test will provide the basis for conclusions drawn about the nature of the objects or events being tested.

Perseverance

When students are able to proceed with their planned investigation, and not give up due to frustration or lack of

interest, they are exhibiting perseverance. Students need to develop the ability to maintain action long enough to achieve results. This requires a certain degree of maturity (not necessarily correlated to age) and self control, implying a higher level of functioning than simply allowing boredom or frustration to direct the learning.

Outcome Evaluation

Outcome evaluation includes the ability to consider all variables involved, any changes or adjustments made during the procedures, and the resultant findings. Once students have drawn closure to the activity, they must determine the results in relation to the hypothesis. The results must be assessed for validity, and substantiated by data gathered during the activity.

Recycle for Input

Occasionally, students need to recycle for input; in other words, more information must be gathered based on unexpected results. Students must be able to establish clear expectations for events, and should realize when data is insufficient to support their testing. The need for more information should not be seen as a failure; rather, it should be a positive sign of cognitive ability.

Implication

The implication of a decision should be considered before beginning. Students should be thinking about what

will happen long before it actually occurs. The consequences of their actions should be largely predetermined. This accompanies the ability to hypothesize and predict.

Transfer

When students' cognitive functions are operating efficiently, new information will be linked to old, and a transfer of knowledge will occur. New findings will be compared and connected to what the student already knows, based on past experiences and prior learning. That old knowledge will then be used to influence their thinking about the new. For example, what students already know about magnets might lead them to a more accurate hypothesis about electromagnetic energy in a new situation.

Decision

Students need to be able to make their own judgments and decisions regarding the progress of their activity. Decisions must be made about if and when to change approaches, what other variables might be involved, and when to move to the next step in the process. Most importantly, students must be able to decide for themselves when to bring closure to the activity. They need to judge results and determine if further investigation is necessary or desirable.

Representation

Representation is similar to the input function of symbolization. Students must be ready to use pictures, sketches, actions, or other thought forms to improve their understanding of objects and events. However, because representation is in the elaborating domain, more than just gathering information must now occur. Representation must also include processing and acting on information using thought forms other than verbal or written.

Extension

This third set of functions, extension, refers to thinking processes which allow students to communicate their thinking to others. Students need to express their data, findings, and conclusions using clear, precise language. Extension includes both written and verbal language.

Representation Expression

Students need to be able to use language to explain their findings by using representation expression. Both written and oral communications must include relevant vocabulary, organized structure, and a transfer of thought and meaning. If students lack understanding of key vocabulary, their representation of findings will not be as successful. They must be able to convey their meaning to others.

Rehearsal

When students are able to think before they speak, they can be said to have used rehearsal for their communication. Taking time to think about vocabulary, word choice, and structure, students can communicate on a much higher level than if they simply blurted out whatever came to their mind first. With rehearsal students can learn to avoid acting on impulse, answering too soon or saying something they might later regret.

Adapted language

Adapted language involves being able to choose words or phrases which would convey thoughts most accurately, while still maintaining comprehension. For students, this means being capable of applying word choice skills based on an understanding of the audience. Different levels of vocabulary and sentence structure would allow the students to express their thoughts to a variety of audiences. Students would be expected to explain an experiment differently to the teacher than they would to their younger siblings.

Precise language

Precise language is vital when communicating scientific thought. If students are to communicate accurately, then they must be capable of employing clear, exact terminology. A lapse in accuracy could result in a failed procedure, with

possible danger to other students. When students explain procedures they must be aware of subtle changes which might lead to significant mistakes. For example, "one liter of sulfuric acid" is quite different than "one milliliter" of the same substance. In this same scenario, it would never suffice to say, "about half-full," instead of using the precise measurement.

Intellectual courage

Intellectual courage is, as the title implies, having enough courage to defend one's ideas or thoughts. Students who show intellectual courage would display strong self-esteem and confidence in their behaviors. Such students show a clear understanding of their activities, and are convinced that their findings are accurate. They are then impelled to share that with others, explaining themselves until they have successfully communicated their message.

Self-Monitoring

When students are able to maintain an awareness of their behaviors and the associated consequences of those behaviors, they display self-monitoring skills. This level of cognition involves students moving past ego-centric types of thinking, toward being able to think about themselves in a more abstract manner.

Intellectual Humility

Being open to suggestions and able to receive feedback from others shows intellectual humility. Students need to accept that they do not know everything, and that it is acceptable to make mistakes. It is important that students accept the notion that there are others who know more than them, and therefore, it is important to receive from more knowledgeable people.

Self-Correcting

Self-correcting is then the next step from self-monitoring. Being able to learn from one's mistakes shows a high level of maturity and humility. Students who are unwilling to admit to their mistakes, or who are unwilling to change their behaviors are not Self-Correcting students.

CHAPTER FOUR: SCIENTIFIC TALENT ENRICHED PERFORMANCE SYSTEM

The Scientific Talent Enriched Performance System (STEPS) is an after-school science program which offers elementary students qualitatively different experiences in science, beyond those they receive in their daily classrooms. The program was designed by Lynne T. Díaz-Rico, Ed.D. and Joseph Jesunathadas, Ed.D., both of whom are professors of education at California State University, San Bernardino (CSUSB). The goals of STEPS are to identify students with interest and talent in science; to provide an enrichment program for students with interest and talent in science; and to maintain an individual record or profile that serves as a progressive assessment of individual achievement, interest, and talent in science.

The program was developed to link research on critical thinking processes and cognitive functions to improvement in science processes. The cognitive functions list presented in Chapter Three was implemented to help students begin to express their scientific thinking in terms of functions. Given that expressing one's thinking and reasoning in science is language dependent (with the exception of pictorial or representational expression) the list of cognitive functions became an important tool for both students and facilitators.

Although none of the students who participated in the STEPS program were non-English proficient, it was apparent to the facilitators that the use of language in science was vital to student success on many levels. Students used language to gather information, develop hypotheses, carry out investigations, and discuss and analyze results. Students who attended regularly began to use a common vocabulary of academic terms specific to the activities presented. Their cognitive academic language proficiency was increased.

The program ran from February to June of 1997. The after-school sessions met each Thursday from 3:45-5:15 (90 minutes). Instruction was provided by the team of two university educators and two elementary school teachers (CSUSB graduate students).

Students who participated in this program did so on a voluntary basis. They were in fifth or sixth grades at a year-round elementary school in San Bernardino, ranging in age from 10 years, 5 months (10-5) to 11 years, 11 months (11-11) old. Before the students could begin attending STEPS, they secured permission from their parents. Interest surveys were distributed to all 128 fifth and sixth grade students at the host site. Of those 128 students, 25 students responded to the interest survey and attended one or more STEPS sessions. Of those 25 students, there was a

core group of eleven who attended regularly and exhibited positive behaviors during instruction and exploration time.

The program used the FOSS science Models and Designs module. Since the FOSS curriculum is not the district's adopted science program, the students had no prior experience with the module. As students worked on the science activities, program facilitators observed and recorded individual performance and interacted with students to assess their scientific process thinking. Facilitators used concept attainment quizzes, anecdotal records, checklists of cognitive functions, and taped interviews with students to establish records of growth, interest, and talent in science.

Children's verbal and written responses to the FOSS activities were recorded in order to discover the cognitive functions "in action." The following examples of student responses serve to illustrate cognitive functions as they were observed in the students during the FOSS science activities.

As suggested in the FOSS curriculum, students were encouraged to work in cooperative groups. Several lessons were conducted with students working in groups of four. However, due to student complaints and noticeable tension in some groups, students were allowed to work with a partner. Because the development of CALP was also a focus of this

project, social interaction between students was crucial. Without the language generated by students interacting with one another and with facilitators, assessment would have been virtually impossible.

In order to gain insights into the students' cognitive functions and scientific thinking, facilitators used four methods of assessment. First, much data was gathered through observation of the students interacting with the science materials and other students in their group. Anecdotal notes were recorded on index cards, and checklists were used to assist facilitators in documenting findings for use in case studies. Second, data was gathered during oral debriefing sessions at the close of each meeting. Students volunteered to report to the class about their progress and findings during that session. Facilitators took anecdotal notes and used checklists of cognitive functions to identify strengths and weaknesses. Third, at the conclusion of the lessons (or the introduction of a new lesson), students were asked to respond in writing to concept attainment quizzes; questions were asked to assess comprehension of the academic content of the activities. These written responses were then scored using a three-point rubric according to the amount of accurate information represented (see Tools for Teachers, p. 120). Fourth, students were interviewed and their responses were recorded on tape. These tapes were

then transcribed by facilitators and used to support other evidence as noted above.

Based on interview data, the students' prior knowledge about science was fairly limited. Students were asked if they knew anyone who was a scientist, and the only one they could think of was Dr. Jesunathadas, one of the facilitators. Their awareness of science in "the real world" was limited to Michele's father who, "mixes chemicals, or something" at work. Many vocalized that science "is finding out about stuff," and, "doing experiments." The students' image of the mad scientist in a white lab coat exposes a stereotypical and narrow view of science as something foreign to schooling and education.

During the course of the STEPS program, the students participated in their school Science Fair. Each student was to create a scientific investigation based on the scientific process (question, research, hypothesis, procedures, observations, results, data, and conclusions). The classes then held a competition for the best projects. We asked the students if they would allow us to review their Science Fair projects. All projects were found to be lacking evidence of the scientific process. The presentation boards were unsystematically organized, not accompanied by supportive data (journals or daily records), and many were obviously

completed without adult supervision or assistance. The overall quality of the students' projects may have been indicative of a lack of classroom instruction regarding the scientific process.

In contrast to their weak prior involvement with science, during the after-school STEPS sessions, most of the students became active learners, participating in activities with interest and enthusiasm.

Miriam

Miriam was a Caucasian fifth grade student whose age at the onset of the STEPS program was 10-5. The results of her interview demonstrated Miriam's limited prior knowledge about science. She described a scientist as someone who "answers questions and uses chemicals." The only scientist she was able to identify was Dr. Jesunathadas. Miriam stated that she wants to be a math teacher when she grows up. She explained that she likes "solving math problems that are complicated (like fractions)." Interestingly, Miriam did not make any connection from complicated math problems to complicated science problems. The two fields were seemingly unrelated in her mind.

Exploration

Miriam appeared to have an adequate amount of the first phase of cognitive functions. She demonstrated at each STEPS session that she could focus by attending to the task

at hand. She stayed involved and on-task, and was able to complete the activity to her satisfaction.

Miriam also remained open to new ideas and was willing to take risks and explore. When a facilitator suggested that Miriam try coiling the wires differently, she readily complied and explored this new method.

When working to build a tower from straws, Miriam reported that, "When I built the tower too high it fell over." This demonstrated that she had used pre-analysis to distinguish the critical aspects of her structure when creating a tower of straws (that the construction must be such that the tower stands alone). She also exhibited pre-analysis when working on an electric motor. She was able to determine that the coil was one of the critical features of the motor.

Miriam was able to label elements of her investigation accurately. She frequently used appropriate vocabulary when reporting to the class of interacting with facilitators. She used the terms "coil," "magnetism," and "force" accurately when describing her ideas about the motor she had constructed. During this activity in which students were to construct an operating motor (using wire, a battery, a couple of paper clips, and magnets) Miriam reported that the way to make the motor stronger was to "take time to work with it." Cognitively, this response revealed a lack of

selective reception. She apparently did not realize that the strength of the motor depended on the interactions of the magnets, battery, and coil. She then added that, "less magnetism would make it stronger because there wouldn't be as much force and it would be easier to move it." Evidently, Miriam was describing the movement of the coil above the magnets. However, her response displayed her lack of understanding that the magnet provided part of the force which resulted in the movement of the coil.

Elaboration

In sharing her ideas about the motor with me, Miriam used the term "symmetry" when describing the coil she made for her motor. She explained that if her coil were more symmetrical it would spin faster, thus her comment about taking time to work with the motor. She transferred her knowledge of the term "symmetry" from another setting, and applied it to the current situation. Although she did not label it as such, she was indeed formulating a hypothesis about the shape of the coil and its effect on the operation of the motor.

Extension

When reporting verbally to the class, Miriam was able to use representational expression. In other words, she expressed her thoughts and actions clearly to others using language. Observational notes indicated that Miriam's

reporting was "clear, to the point, easy to follow." This would suggest that she used adapted language, resulting in an explanation that the audience could understand.

Sean

Sean was a Caucasian sixth grade student whose age at the onset of the STEPS program was 11-11. He described a scientist as "a person who figures out questions." He explained that in his view, a scientist must be patient, smart, and willing to "look into things. You just don't look at it and say, 'It's not going to work.' You have to try different things." Sean explained that science was all around him, "t.v., everything. Everything that was made, a scientist had to make it or someone had to test it many times to get the t.v. that you have or the radio that you have." These responses exhibited this student's strong prior knowledge about the nature of science. He said that he was a scientist "at this point," referring to his actions in the STEPS program. However, when asked if he envisioned himself with a future career in science he replied that he did not.

In response to a question about how he felt he learned science best, Sean answered, "through hands-on activities...because you're not just reading about it, you're actually doing what they're talking about." Sean was able to identify a scientist he knew. He said that his

mother's best friend's husband was "an oil scientist." He then went on to explain that his father "delivers the equipment they use to build new buildings." He related that the scientific content of that job was in the computers and phones his dad used.

Exploration

Sean was an eager learner, participating with openness and focus at each STEPS session. While he did appear to have a strong background with science experiences, his inaccurate use of terms revealed a possible deficit in labeling. He included terms such as "electrons," "coil," "axle," and "sphere" in his reports to the class. However, he tried to explain that the reason the coil was important to the operation of the motor was that electrons spun around the wire, thus producing the energy to run the motor. Although his reports sounded impressive, they actually were quite weak in terms of scientific accuracy. He introduced vocabulary words which revealed many naive conceptions he held.

Elaboration

While working with an electromagnet, Sean commented that he had seen a real electromagnet at a junkyard. He explained that it was used to pick up the crushed cars and move them around the junkyard. He had observed the junkyard magnet in operation; he successfully represented that idea

to me; he transferred knowledge from that observation to the activity at hand; he had relied on inferences based on that observation to support his thinking; and he had applied his prior knowledge and observation to creating his own electromagnet.

He later exhibited metaphorical thinking when he related the axle on his go-cart to the axle of an automobile. Although this analogy was not too abstract, it did provide evidence that this student was capable of thinking beyond the present situation. His use of scientific terminology illustrated his attempt to use precise language.

Extension

Sean was an eager reporter for his groups. As has been noted, his reports often revealed his misuse of scientific terms. He was, however, clearly able to use representational language to transport his mental thinking.

Another function of extension, rehearsal, also appeared to be a weakness for Sean. Even after the class had been reminded to "think about your reporting and plan what you will say," his reports still were a bit impulsive. In one case he said only that his group didn't get along and that he had done all the work. This was judged as being impulsive because he had not really responded to the prompt of reporting his thinking and findings to the class. Even

after a facilitator's attempt to refocus Sean on his report, he simply said, "I guess that's all."

Michelle

Michelle was a Caucasian sixth grade student whose age at the onset of the STEPS program was 11-8. She described a scientist as a "goofy man in a white, like, apron thing, using scientist bottles and mixing chemicals." While somewhat humorous, her stereotypic image of a male scientist wearing a white lab coat was indicative of a low level of prior knowledge about the field of science. She reported to facilitators that she did not use science at home. She stated that she plans to have a career "working for the state as a detective or firefighter," but she did not acknowledge that there is science involved in either situation.

Exploration

Michelle was an enthusiastic student who demonstrated focus and openness by being able to remain attentive to the task at hand and willing to explore and investigate.

Elaboration

During the motor-making activity, Michelle was asked to develop a hypothesis regarding how she could make her battery-operated motor stronger. She replied that she would test the motor with the "paper clips straight." She had decided that the reason her motor did not run efficiently

was because the paper clips were bent. She made the logical assumption that by straightening the clips, the motor might be improved. Inference in her thinking was evidenced by her ability to create a new idea based on past experience. She had relied on her observation of her motor; she had compared the level of efficiency of her motor to that of others'; she had spatially organized her materials to create the effect she desired; and she was able to relate the effect (the speed at which her motor operated) to the possible cause (the straightness of the paper clips). Her ability to formulate hypotheses demonstrated the fact that she can guess about the relationship between variables, and plan a way to test that hypothesis. Her hypothesis thus provided evidence of many different cognitive functions involved in her thinking.

Observational notes also indicated that Michelle displayed an ability to maintain mentation, or thinking processes, and defend against interruptions. She was able to remain on task, even when others around her were exhibiting distracting behaviors. Specifically, she kept working on her go-cart while one of the members of her cooperative group playfully rolled the wooden wheels across the floor.

Extension

Michelle did not know the term for a lab coat, calling it instead "a white, like, apron thing." This lack of vocabulary could easily be attributed to her apparent lack of exposure to science, rather than a possible deficit in labeling. Given that the term "lab coat" had not been introduced formally, this substitution was not deemed indicative of her labeling skills. Rather, it provided some insight into Michelle's ability to describe an object understandably to her audience; she had used adapted language.

During one of her reports to the class, Michelle organized her presentation sequentially to describe the steps of her procedure saying, "First, I did this; second I..." etc. This shows an ability to combine the logical structure of language (the ordinals) with a seemingly logical sequence of thought.

During her interview, Michelle used precise language to express herself. She said that the coil on her motor needed a better "line of symmetry." It was noted that Miriam had also used the term "symmetry." Observational notes indicated that Michelle had been nearby when Miriam was interviewed, and had most likely overheard her use of the term. Nonetheless, she was able to rely on that prior experience with the term and apply it to her own situation.

Like Miriam and Sean, Michelle demonstrated a wide variety of cognitive functions and thinking abilities.

Summary

In the three case studies presented, the students were found to be functioning at different cognitive levels. The case studies helped illustrate that children will employ cognitive functions according to their individual readiness for each. While it is beyond the scope of this project to determine students' individual developmental levels, it does appear that their level of functioning in science might be indicative of their exposure to the field in general.

The observational notes regarding CALP and the cognitive functions checklist used in this project were found to be useful for facilitators. Both tools allowed for effective documentation of student behaviors and thinking patterns. When combined with information from concept attainment quizzes and personal interviews, facilitators were able to gain insights into the individual strengths and weaknesses in science for each student who participated in the STEPS program. Such information could prove quite useful to classroom teachers in the continual assessment and improvement of their academic programs.

Specific information regarding individual students' concept development needs to be explored in greater detail. In reflecting on the results of this project, it appears to

me that I am left with more questions than answers. Given the information gained about students' cognitive functions, what are the implications on classroom pedagogies? How do students' learning styles affect their cognitive functioning in science? Would teaching the students about cognitive functions improve their performance in science?

As a teacher, I am constantly reminded of the need to aggressively meet the challenge of improving the education of our children. Educators at all levels must attempt to better our educational system in order to allow children to meet the demands of an ever-changing world.

CHAPTER FIVE: RECOMMENDATIONS TO TEACHERS WHO USE FOSS

The teacher's resource guide (Appendix A, p. 108) presents ways teachers can support cognitive functions and CALP for English language learners. The activities and tools contained in the guide are based on the following recommendations:

1. Identify where in the lesson specific functions can be addressed, and what those functions are. If teachers are provided with a "map" that isolates related steps of the activity and identifies the functions relative to those steps, they could then become better able to support students' thinking and processing as the lesson progresses. This type of ongoing, interactive support is a powerful use of dynamic assessment strategies.

Based on experiences with the students in the STEPS after-school science program (described in Chapter Four) it is recommended that teachers focus on no more than five cognitive functions at a time. Although it is recognized that many functions are quite similar (such as symbolization and representation), and unexpected functions will be seen in students, it is not practical to try to associate an action to one of 40 functions. Rather, if teachers are looking for a targeted three to five functions, they are more likely to know what they are looking for and recognized the function when they see it.

2. Identify cognitive academic language students need to use as they progress through the lesson. Teachers need to be able to recognize the language students need, associated with the functions of each step. For example, when teachers hear students saying, "I wonder what would happen if I made this wheel bigger," they should be able to identify that type of thinking as formulating hypotheses. On the other hand, teachers should also be aware of language that might indicate inaccuracies in students' thinking. When students say that they "changed the things that touch the battery," teachers might recognize a deficiency in labeling or adapted language.

3. Provide interactive and supportive phrases for teachers to use in association with specific functions. Once a function has been identified as a possible deficit for students, teachers can provide careful intervention that will guide students toward clarity of thought and possible corrective actions. This intervention must take the form of suggestions and hints, without revealing too much information toward the solution. If teachers simply say, "No, the wheel should be larger," then students are not given the opportunity they deserve to increase their thinking and learning abilities.

APPENDICES

TABLE OF CONTENTS

Appendix A: Cognitive Functions Correlation to FOSS Models and Designs: Black Boxes Activity.....108

Appendix B: Activities to Support English Language Learners.....135

Appendix C: Tools for Teachers.....144

APPENDIX A

Teacher's Resource Guide

Introduction

The importance of teaching students to be thinkers and speakers in science extends beyond the school setting. Students who are able to reason, think, and communicate about scientific issues will benefit in all areas of their lives. It is our responsibility as educators to provide a curriculum which fosters critical thinking in academic content areas for all students, including English language learners (ELLs). It is hoped that this resource guide will assist all educators, not just those who work with English language learners.

As ELLs increase their cognitive academic language proficiency (CALP), they will develop critical thinking, using skills such as relating and organizing the input they receive. High level critical thinking and cognitive functions will be necessary for their academic growth. These cognitive functions will, in turn, be further developed as they are used more often during the process of learning.

The resource guide is intended to provide a means of identifying cognitive functions and CALP using dynamic assessment techniques in conjunction with Full Option

Science System (FOSS) science activities. These strategies might also be adapted and modified so that they can be applied to other FOSS activities, science programs, or curricular areas.

Cognitive Functions Correlation to FOSS Models and Designs: Black Boxes Activity

Appendix A contains a chart which guides teachers through the FOSS Black Boxes activity. The first column of the chart, entitled "FOSS Activity: Black Boxes," leads the teacher through the activity, identifying steps as they are numbered in the FOSS activity guide. These segments of instruction have been chunked, or grouped, according to similarities in their purposes and processes of the lesson. The descriptions in this column are intentionally abbreviated, serving only to orient teachers to the activity proceedings. (For specific lesson details, refer to the FOSS activity guide, pp. 113-125.)

The second column, entitled "Cognitive Functions," refers to the synthesis of science processes and critical thinking as described in Chapter Three. (For an annotated list, see Tools for Teachers, p. 144.) No more than five cognitive functions have been listed for each step of the activity. While it is true that most steps involve many cognitive functions at once, it may be too difficult to accurately identify functions based on a list of 40.

Narrowing the focus allows teachers to more readily identify functions as they are occurring. Following the listing for each function that involves the use of language, a brief sample of possible student verbalizations are given. These examples are intended to help teachers identify the function as it might manifest in student talk. It should be noted that this list is not intended to be comprehensive; rather, it is specific to this activity. It is neither necessary nor efficient to attempt to identify all cognitive functions based on one activity. Teachers need to be familiar with all 40 functions in order to recognize those not listed here as they might possibly occur during investigations.

The third column of the chart, entitled "Cognitive Academic Language Proficiency," assists teachers in identifying key vocabulary with which English language learners might need support. Key terms are listed in the order they initially occur during the sequence of the lesson. The list is cumulative and inclusive; that is, terms listed in step five include all terms needed from step one through step five. Although vocabulary is only part of cognitive academic language proficiency, it is used here to help teachers identify words and/or concepts vital to students' understanding the content of the lesson.

The fourth column of the chart, entitled "Dynamic Assessment Prompts," offers teachers possible hints, or

prompts, to provide students as they progress through the activity. These are merely suggested questions and comments. What is important is the act of supporting learners' cognitive functions, interacting with students as they process information, not necessarily repeating the same questions or hints to all students. The dynamic assessment strategies offered in this column must be applied based on professional judgment.

Activities to Support English Language Learners

Appendix B contains suggested strategies and activities specifically designed to support English language learners. Each activity is related to the content of the FOSS Black Boxes activity. These activities may be used with the entire class for vocabulary development, or with small groups of ELLs only. The activities might easily be adapted and modified so that they can be applied to other FOSS activities or science topics.

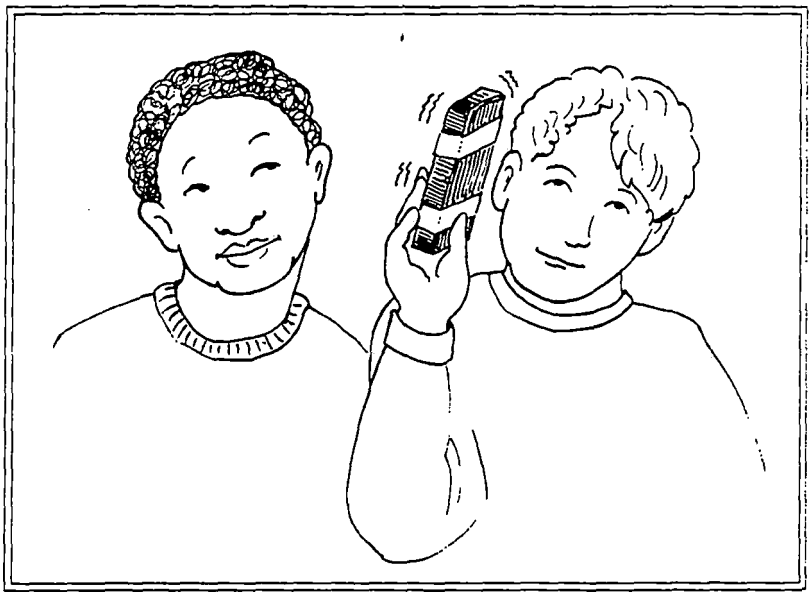
Tools for Teachers

Appendix C contains reproducible pages designed to assist teachers in identifying students' cognitive functions, science processes, and cognitive academic language proficiency using dynamic assessment strategies. These rubrics and checklists might be a valuable addition to a students' collection of work samples and assessment

instruments (many educators now assemble such a collection in a student portfolio).

BLACK BOXES

ACTIVITY 1



STRAND

Scientific Reasoning and Technology

SCIENCE CONCEPTS

Black box
Model

SCIENCE THINKING PROCESSES

Observing
Communicating
Comparing
Organizing
Relating

INTERDISCIPLINARY ACTIVITIES

Language

PURPOSE

In *Black Boxes* the students will

- Make multisensory observations of black boxes.
- Develop conceptual models of black boxes.
- Communicate models through discussion and drawing.
- Construct concrete models to compare to conceptual models.
- Learn concepts that will contribute to understanding of the following themes: **Structure, Interaction,** and **System.**

THEMES

Structure
Interaction
System

OVERVIEW

In *Black Boxes* the class is presented with a set of 16 sealed black plastic boxes—four labeled *A*, four labeled *B*, four labeled *C*, and four labeled *D*. Students work in pairs with one box to determine what is inside. After 15 minutes, a student from each pair draws a picture on the board (model) that explains what the pair thinks the inside of their box looks like. The students then form into four groups, with everyone who investigated *A* in one group, *B* in another group, and so on. After 15 minutes, a spokesperson for each group draws the consensus model for what the group thinks the box looks like inside. The activity concludes with a discussion of models, sensory information, and methods for improving the models.

2 BACKGROUND FOR THE TEACHER

Black boxes were created at the Lawrence Hall of Science more than 25 years ago. They have since been used by science instructors and curriculum developers in many different ways. The FOSS program uses the term *black box* to mean any system that cannot be observed and manipulated directly or understood completely. Many things cannot be seen directly—atomic nuclei, the origin of the universe, the earth's core, magnetism, dinosaurs, and so on. In each case, the subject of interest is remote in time or space or hidden from our powers to observe. A color TV is a black box in the sense that it is incomprehensible in everyday terms. Electricity goes in and a picture miraculously appears on the screen. Even the telephone is a black box. We think nothing of dialing a number to speak with a person across the continent, never questioning how this is possible.

Some black boxes are incomprehensible because our sensory access to them is incomplete. Perhaps, like dinosaurs, the subject of interest existed in the past. Or maybe, as in the case of the earth's core, the subject is sealed off from access. However, if we are able to gather a few facts about a black box, we can start to develop a working idea about what it looks like, how it works, what it is made of, and so on. When we do this, we are building a model.

A **model** is a representation or explanation of reality that is sufficiently accurate and complete so that it allows the holder of the model to predict events. The development of a model often progresses through several stages. First an individual approaches an unknown (black box), makes observations, and organizes those observations into a tentative model that explains the unknown. As a result of discussion with others (collaboration) and additional observations (testing), the model may be revised or improved. Eventually a consensus model evolves that will explain the reality for everyone—that is, until new information suggests the need for a better model.

That is what your students will do in this activity. The unknown is a real black box made of plastic. The question is, "What does the inside of the box look like?" At first the students will not know, but as they tip, turn, and shake the box, they will start to get an idea of what is inside. By systematically feeling and listening to the interactions occurring in the box, the students will gather enough evidence to build a conceptual model, and with help from other students in the class, they will refine it. In this way your students will apply the skills and procedures that scientists use to discover things about the world that they can't observe directly.

And what about the conclusion of the activity? Are the boxes opened to verify the accuracy of the models? It's your choice, but the FOSS position is that you should *never* open the boxes. That would bring the activity to an end, thus spoiling the wonderful feeling of personal accomplishment and quieting that delightful nagging inner voice that puzzles, "I wonder, could I improve the model if I were to...?"

In the real world of science, scientists don't always have the answers. They, too, have to rely on the best available model to explain how the world works.

MATERIALS

For each team of two students
- 1 Black box, labeled *A, B, C,* or *D* (See Step 2 of Getting Ready.)
- • Scratch paper*

For the class
- 50 Triwall cardboard triangles
- 50 Triwall cardboard rectangles
- 16 Black boxes, empty
- 40 Glass marbles
- 1 Roll of electrician's tape, black
- • Labels for the black boxes (dots, 3/4" diameter)
- 1 Permanent marking pen*
- • Masking tape
- 1 Drought stopper apparatus
  - 2 Pieces of clear plastic tubing
  - 1 Funnel
  - 1 1-liter container with hole
  - 1 Cardboard box, small
- Δ 2 Basins
- Δ 1 Beaker, 1000-ml
- Δ 1 Beaker, 100-ml
- • Water*
- 1 MAP sheet called *Black Box Schematics*
- 1 MAP sheet called *Mystery Box Ideas*

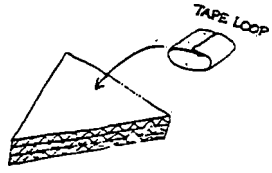
* Supplied by the teacher
Δ FOSS **Measurement** kit item

4 GETTING READY

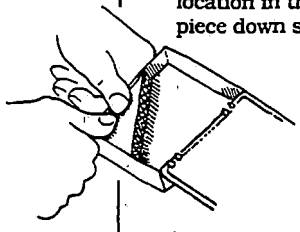
1. **Schedule the Activity.** This activity is written in three parts. Part 1 requires one session of 40 to 50 minutes, but may be conducted in two 30-minute sessions. Part 2 can be conducted in 40 to 50 minutes. Part 3 requires two 40- to 50-minute sessions to complete.

2. **Prepare the Black Boxes.** Prepare 16 black boxes as per the *Black Box Schematics* sheet—four As, four Bs, four Cs, and four Ds.

a. Form an 8-centimeter piece of masking tape into a loop, sticky side out.

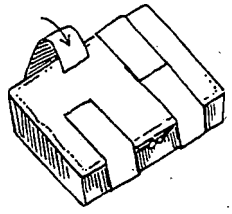


b. Stick it to the back of a cardboard shape, and position the shape in the proper location in the box. Press the piece down securely.



NOTE: For additional security you may want to wrap tape around the box the long way.

c. Put a marble into the box, close it, and tape it tightly shut with electrician's tape, wrapping the tape around the boxes in two places.

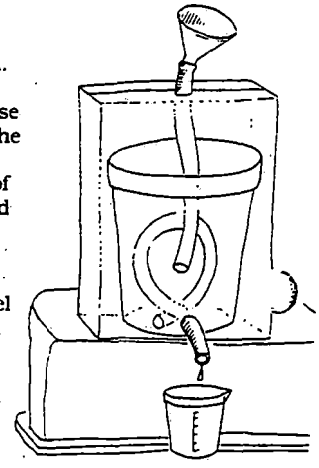


d. Label the box with its letter (A, B, C, or D), using the dots supplied.

3. **Keep the Black Boxes Closed.** It is strongly recommended that the boxes *never* be opened for the students to see inside. If you feel as strongly about this as we do, get some good plastic glue and glue the triwall cardboard pieces in place and then *glue the boxes shut.*

NOTE: Use a permanent marking pen to write the box letter on the dot.

4. **Plan for the Drought Stopper Demonstration.** The drought stopper is a self-starting siphon system. It is composed of a 1-liter container with a loop of hose (tubing) in it. One end of the hose sticks out *and down* from a hole in the bottom of the container; the other end rests on the bottom of the container.



A second hose with a funnel in one end is used to direct water into the 1-liter container. The whole setup is hidden inside a small cardboard box.

Set it up as illustrated, using one basin to support the system, and another to catch any water that might spill.

It is very important to practice using the drought stopper a few times to get the feel for it. Pour about 400 milliliters of water into the liter container. The water level should reach a level *just below the top of the loop* of the hose. The demonstration is primed. Any additional water added to the system will cause the top of the loop in the hose to be submerged under water and the siphon will start.

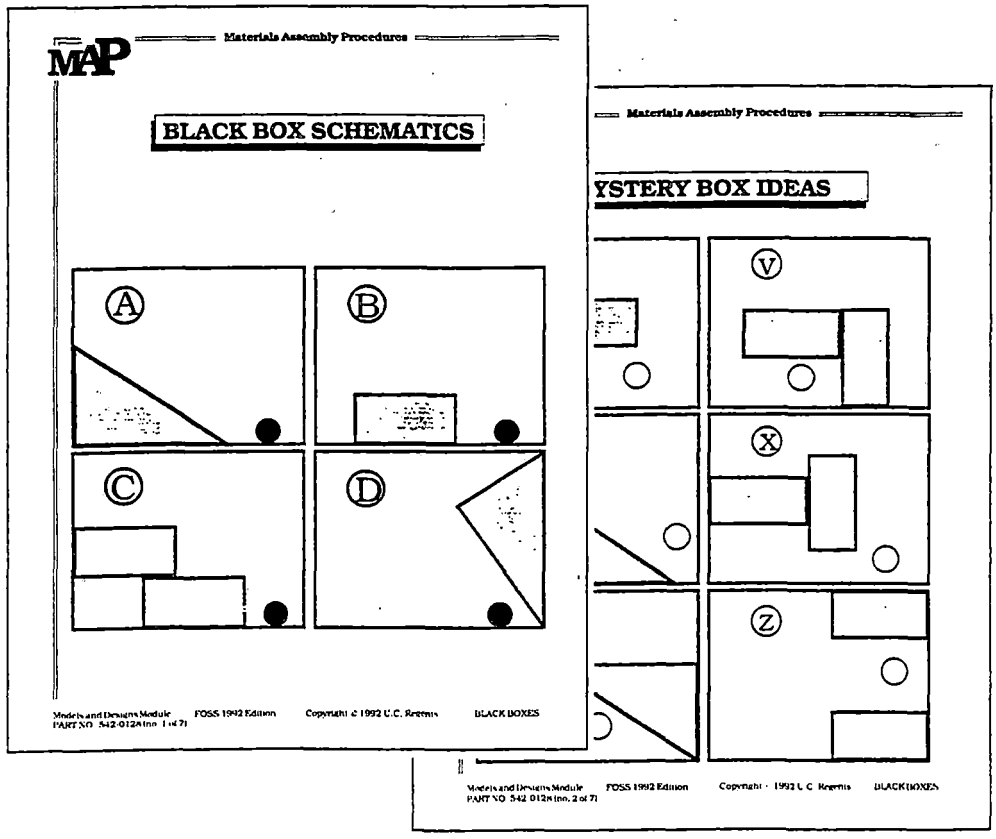
GETTING READY

NOTE: Figure out just how much water your drought stopper needs for priming.

To conduct the demonstration, put the 1-liter container in the box and prime it with water. Carefully carry it to a central location where everyone will be able to see. At show time, pour in an additional 100 ml of water, and the siphon will start. Have the liter beaker handy—500 ml of water will flow out! Catch some of the water in the 100-ml beaker. When the students see the 100-ml beaker overflow, they will be surprised. Practice to get the prime volume of water just right.

5. **Set Up a Materials Station.** Plan to organize the materials for the activity in a convenient location where the GETTER from each team or group can get materials.

STUDENT SHEETS



6 DOING THE ACTIVITY

Part 1: Black Box Investigations

1. **Introduce the Black Box Challenge.** Hold up a black box. Shake it gently and tell the students that there is something inside, but you don't know what, and you can't look because the box can't be opened. Their challenge will be to figure out *what the box looks like inside.*

2. **Form Teams of Two.** Have the students work in pairs. One student will be the STARTER; the other, the RECORDER. Each team will investigate one box. Instruct the students to take turns with the box so everyone has a chance to participate in the investigation.

3. **Give the Rules.** To prevent damage to the boxes, explain the rules of investigation.

- The boxes remain closed.
- No drawing on the boxes, even with erasers.
- No violent shaking or hard pressing—boxes can break.

NOTE: Violent shaking will break the boxes.

4. **Assign Boxes.** Point to each team and assign a box for investigation by calling a letter. Go in sequence: A, B, C, D, A, B, etc. In this way, teams close to one another will not work on boxes with the same letter.

MATERIALS:
1 Box, labeled
• Scratch paper

Have the STARTERs go to the materials station to get a box with their assigned letter. Let the teams start to figure out what the box looks like inside.

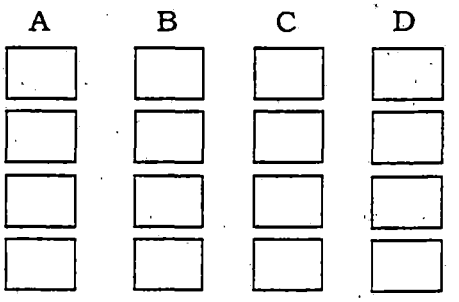
5. **Identify the Marble.** After two or three minutes, ask the students what they have discovered. When someone suggests that there is a marble in the box, ask for a show of hands from those who agree. Confirm that each box has a marble.

Encourage the students to concentrate on the *locations* and *shapes* of things in the boxes, not the material from which they are made.

Suggest to the students that drawing pictures or diagrams might help them figure out what's inside the boxes, but tell them *not* to write or draw on the boxes themselves. Let them continue exploring.

6. **Prepare Outlines on the Board.** While the students work on the boxes, draw 16 large box outlines on the board—four under a letter A, four under a letter B, four under C, and four under D. Space the columns a meter apart.

NOTE: Draw rectangles about 12 by 15 cm.



7. **Explain Drawing Box Contents.** After the students have been working 10 to 15 minutes, call for attention and explain that the RECORDER from each team will come to the board and draw what their box looks like inside. Emphasize that the four boxes under the letter A are to be used by the RECORDERs investigating box A.

8. **Draw Box Contents.** Invite RECORDERs from teams that are ready to come up immediately; the others can work with their boxes a few minutes longer. It should be possible to have about eight students at the board at a time.

9. **Introduce Model.** When the drawings are on the board, tell the students that the pictures they have drawn are **models** of black boxes.

People make models of things that are very big, like the solar system, things that are very small, like atoms, and things that are impossible to see into, like black boxes. A ***model*** *is a representation or explanation of something that shows how it looks or works.*

10. **Interpret the Students' Models.** Point to each model in turn, interpreting what you see. Say things like, "The creators of this model think there is a triangle-shaped object in the corner of the box; these observers thought there was a netlike fence down the middle of their box; this model shows a square shape..."

11. **Discuss the Making of the Models.** Ask the students what senses they used to explore the boxes. Ask them to demonstrate the techniques they used to investigate the boxes.

BREAK POINT

12. **Describe Scientific Collaboration.** Tell the students.

Scientists often work by themselves on difficult problems for a while and then write articles about what they found out in a science magazine called a journal. Your model drawings are like journal articles. When scientists read the journal articles, they find out who is interested in the same problem they are. They often have conferences where they get together to talk about the problem and to work together on the problem. Working together is called collaboration.

13. **Describe Black Box Conference Groups.** Tell the students that for the next 10 minutes they will work with all other students who originally investigated the same lettered box that they did. Their goal is to share ideas so they can arrive at the best possible model for their black box.

14. **Work Toward Consensus.** Tell the students that *consensus* means everyone agrees. The groups should try to reach consensus on the best model for their boxes, not by vote, but through discussion, observation, testing of ideas, and carefully applied techniques. When consensus has been achieved, a spokesperson (RECORDER) from each group will draw the consensus model on the board.

15. **Provide Hints.** This is an appropriate time to tell the students that *all of the A's are the same, all of the B's are the same, etc.* Also, you may want to hold up one of the triwall cardboard shapes and tell them.

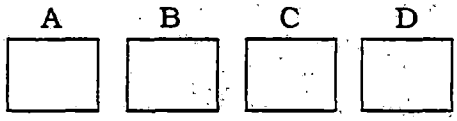
This is an example of the kind of object that is stuck in each box with a marble. It may not be this shape, and I don't know where it is stuck, but this is the kind of material it is made of.

Remind the students to draw models as they work and discuss their ideas.

NOTE: Remind the students not to write or draw on the boxes, but to use paper.

16. **Organize into Conference Groups.** Point to one corner of the room, and tell all of the students with A boxes to go there with their boxes, all the B's to another corner, and so on. Let them begin refining their models.

While the students work on their models, draw four large outlines on the board, and label them A through D.



NOTE: If a group is unable to reach concensus, it is possible for them to contribute two models.

17. **Draw the Consensus Models.** Encourage one RECORDER from each conference group to draw the consensus model on the board in the appropriate box.

18. **Discuss the Final Models.** Congratulate the students. Tell them they have provided the class with an answer to the question, "What do the four boxes look like inside?"

The students may want to open the boxes. Tell them,

There are many things in the world like ***black boxes*** *that can't be opened—the center of the earth, atoms, the sun, etc. We try to understand what they look like and how they work by getting as much information as we can. When we get new information, we change our models to include the new knowledge. Models always represent our best explanation of how things look or work, and models can always change.*

19. **Propose Improving Models.** Tell the students that the boxes will stay closed, but they can continue to improve their models in the future. Ask the students to share some of their ideas about how to improve their models. They may suggest,

- Magnets
- Thin wire probes
- X-rays or strong light
- Building a model and comparing it to the black box

20. **Reveal the Secret?** The FOSS position on black boxes is that you never open them. As long as the boxes stay closed, everyone is right—no one is wrong. Ingenuity and inventiveness can continue to be brought to bear on the subject of black boxes as long as they remain a curiosity. We encourage students to develop confidence in their ideas and intellectual creation; so again, we recommend that *boxes remain closed.*

21. **Close the Activity.** Have the STARTERs return the boxes to the materials station. If the students would like to continue to work on the models of the boxes, leave one set out for informal investigation.

Part 2: Building Black Boxes (Optional)

22. **Build Models for Comparison.** Tell the students that you have some empty black boxes, marbles, and cardboard shapes. Show them how to make a masking-tape loop, sticky side out, to stick cardboard shapes into the boxes. Let the original pairs of students work to build a model that behaves the same as the original black box they worked on.

DOING THE ACTIVITY

MATERIALS:
1 Box, empty
1 Box, labeled
1 Marble
• Cardboard rectangles
• Cardboard triangles
• Masking tape

NOTE: Ask the teams to take a 30-cm strip of tape to their desks and leave the roll at the materials station.

23. **Compare the Models to the Originals.** Put the original black boxes at the materials station. Let the STARTERs pick up their original black box to compare to their model at the same time they pick up empty boxes, marbles, and cardboard pieces. Make masking tape available at the materials station. Let the construction and comparison begin.

24. **Re-form the Conference Groups.** When the teams have built their best models, let them re-form their conference groups to compare the models they built. Based on this experience, let them revise their final models on the chalkboard.

25. **Clean Up.** At the conclusion of the activity, ask the students to remove the triwall cardboard pieces from their boxes and to discard the tape. The marbles, cardboard pieces, and boxes should be repackaged for storage.

Part 3: The Drought Stopper

MATERIALS:
1 Drought stopper
1 Beaker, 1000-ml
1 Beaker, 100-ml
2 Basins
• Water

26. **The Drought Stopper.** The drought stopper is a self-starting siphon system hidden in a box. Set it up as described and illustrated in Step 4 of Getting Ready, making sure that the funnel and hose directs water *into* the liter container in the cardboard box, and that the system is on something high enough to get a basin under the outflow hose.

27. **Prime the System.** Pour about 400 ml of water into the liter container while the students are out of the room.

28. **Demonstrate the Drought Stopper.** When you have their attention, tell the students that you have an invention that will put an end to droughts. Have them watch closely as you pour 100 ml of water into the funnel. Put a 1000-ml beaker under the outflow hose and show them that you can get 500 ml out. Have the students draw a model of what the drought stopper looks like inside.

29. **Play It Again.** Once the trick has been performed, it can be repeated again and again by pouring in 500 ml of water. The last 100 ml will start the siphon and all 500 ml will pour out. Let the students do this as often as necessary to allow them to gain additional information to develop their models. But caution them that they are *not allowed* to pick up, push, tip, or otherwise manipulate the system—just pour water in and observe it come out.

30. **Discuss the Models.** Ask four volunteers to come to the board to draw their models. Let the students explain how their models operate. Then provide time for the other students to ask questions of the students who drew the models. Repeat the process, four students at a time, as long as interest is high.

NOTE: The students should be allowed to run water through the system, but they are not to move the system in any way.

BREAK POINT

10 REFLECTING ON THE ACTIVITY

Good questions can motivate students to think about new ideas and can help them to realize connections to other areas of study. **Recall questions** get them to remember information. **integrating questions** get them to process information. **open-ended questions** get them to infer, create, and solve problems, and **thematic questions** help them realize connections among scientific ideas and processes. Below are examples of these types of questions.

1. What is a model? [A representation or explanation of how a system is constructed or how it works.] (recall)

2. In what ways are black boxes and video games alike? (integrating)

3. Describe your model showing how fast food hamburgers are made: how marshmallows are made: how vending machines work: how a bicycle pump works: how a refrigerator/freezer works: how sound gets off of a cassette: how a person grows. (open-ended)

4. How did you feel when you weren't allowed to open the black boxes at the end of the activity? (feeling)

5. Give examples of models and explain how they are used in biology and in chemistry. (thematic connection: Structure. System)

VOCABULARY DEVELOPMENT

black box: a system that cannot be seen into or understood easily.
model: a representation or explanation of how a system is constructed or how it works.

NOTE: Be sure your students understand and can use these words:
- atom
- consensus
- representation
- results
- senses
- system

LANGUAGE DEVELOPMENT

1. **Black Boxes Everywhere.** Have the students make lists of black boxes they encounter in their lives. A black box is any system or device that works in mysterious or unknown ways. The list could be posted on the bulletin board and increased over a period of days. Start the list with "television" and "telephone."

2. **Model of the Solar System.** Have the students research the Ptolemaic system of the universe and the subsequent modifications that brought our model of the solar system to its present-day form.

EXTENSIONS AND APPLICATIONS 11

1. Introduce U, V, W, X, Y, and Z. You can provide additional challenges for your students by making a few mystery boxes. Follow the suggestions on the *Mystery Boxes* MAP sheet, or invent some designs of your own. Remind the students that the boxes are never to be opened, and that they should never write on the boxes.

2. **Model-building Games.** The kind of thinking that produces interesting models and creative solutions to problems can be exercised with manipulative games like Tangrams, two-coordinate games like Battleship and Hurkle, and pattern games like Master Mind. Also valuable are construction games of the kind where two students are separated by a vision barrier. One student builds a simple structure with blocks while verbally describing her actions; the other student tries to make an exact replica, following the first student's descriptions.

FOSS FOR ALL STUDENTS

Hands-on science provides opportunities for students to learn from each other. The experience will be enriched for students with disabilities and students from culturally and linguistically diverse populations by using specialized tools and procedures where appropriate.

Visually Impaired. Visually impaired students will be able to participate fully in the analysis part of the ***Black Box*** activity. They can prepare their models using a raised-line drawing kit.

Students Learning English. ESL lessons could include descriptive vocabulary of size, location, and shape used in relating positions of unseen objects in the black boxes.

Metaphors such as "black box" can be discussed to help students learn figurative English.

NOTE: This icon alerts you to suggestions for working with diverse populations (see FOSS for All Students in the module *Overview*).

12

ACTIVITY OUTLINE

Part 1: Black Box Investigations

1. Introduce the Black Box Challenge.
2. Form Teams of Two.
3. Give the Rules.
4. Assign Boxes.
5. Identify the Marble.
6. Prepare Outlines on the Board.
7. Explain Drawing Box Contents.
8. Draw Box Contents.
9. Introduce Model.
10. Interpret the Students' Models.
11. Discuss the Making of the Models.
12. Describe Scientific Collaboration.
13. Describe Black Box Conference Groups.
14. Work Toward Consensus.
15. Provide Hints.
16. Organize into Conference Groups.
17. Draw the Consensus Models.
18. Discuss the Final Models.
19. Propose Improving Models.
20. Reveal the Secret?
21. Close the Activity.

Part 2: Building Black Boxes

22. Build Models for Comparison.
23. Compare the Models to the Originals.
24. Re-form the Conference Groups.
25. Clean Up.

Part 3: The Drought Stopper

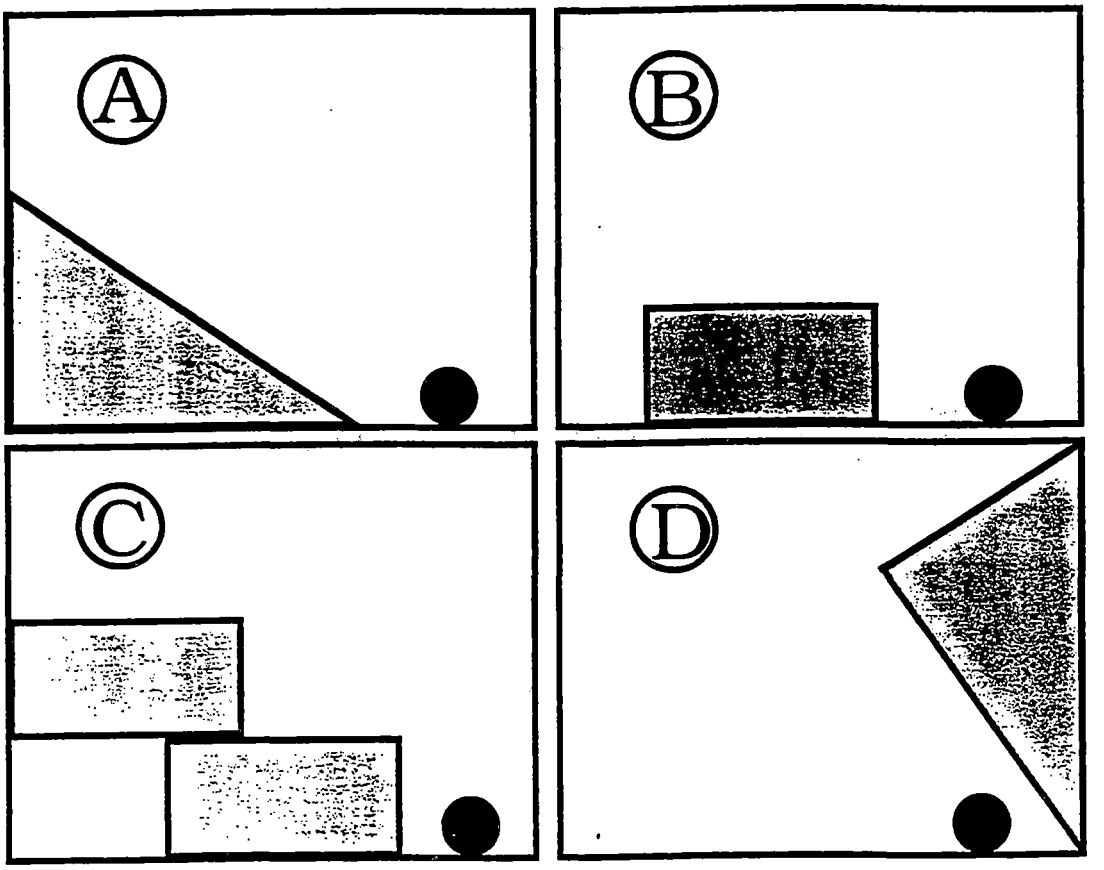
26. The Drought Stopper.
27. Prime the System.
28. Demonstrate the Drought Stopper.
29. Play It Again.
30. Discuss the Models.

Britannica
ENCYCLOPAEDIA BRITANNICA EDUCATIONAL CORPORATION
310 South Michigan Avenue Chicago IL 60604
1-800-554-9862 extension 6554

This material was prepared with the support of National Science Foundation Grant No. MDR-8751727. However, any opinions, findings, conclusions, statements, and recommendations expressed herein are those of the authors and do not necessarily reflect the views of NSF.

Full Option Science System
Lawrence Hall of Science
University of California
Berkeley, CA 94720
1-510-642-8941
FOSS

BLACK BOX SCHEMATICS



Cognitive Functions Correlation to
FOSS Models and Designs Black Box Activity

FOSS Black Box Activity	Cognitive Functions	Cognitive Academic Language Proficiency	Dynamic Assessment Prompts
Steps 1 through 4			
Students examine a black box in order to figure out what the box looks like inside	Openness Focus Spatial *"It's only blocked on the left ..."* Organized investigation *"First I'll . . . then I'll . . ."* Pre-Analysis *"The most important thing about this problem is . . ."*	Black Box Device System	"Try to find out where in the box the object is." "What happens if you turn the box slowly, just one corner at a time?"

Table continues

FOSS Black Box Activity	Cognitive Functions	Cognitive Academic Language Proficiency	Dynamic Assessment Prompts
Step 5			
After students have had two to three minutes to examine the box, they explain what they discovered. The teacher provides confirmation to all that there is a marble in each box.	Representation expression *"I found out that . . ."* *"We think that . . ."* Rehearsal	Marble (moving object) Object Stationary Obstruction	"Take a minute before you speak to think about what you are going to say." "What vocabulary words do you need to use?"

FOSS Black Box Activity	Cognitive Functions	Cognitive Academic Language Proficiency	Dynamic Assessment Prompts
Step 5 (continued)			
Students now continue their investigation of the box, focusing on the locations and shapes of things in the boxes (rather than the material from which they are made.)	Problem definition *" We need t o know . . . "* *"I wan to find out . . ."* Comparison *"There is something that moves and something that does not move."* Formulates hypotheses *"Ithink that . . . "* *"My guess is . . ."*	Positional words: Above, next to, corner, side, etc. Shape words: triangular, square, etc. Density indicators: thick, thin, etc. Location	Concentrate on finding out the shape and location of the objects in the box.

FOSS Black Box Activity	Cognitive Functions	Cognitive Academic Language Proficiency	Dynamic Assessment Prompts
Step 5 (continued)			
Students may choose to draw pictures or diagrams as suggested.	Representation Expansion	(no verbalization necessary)	"What else can you tell about the things inside the box just by thinking about the drawing you have made."

FOSS Black Box Activity	Cognitive Functions	Cognitive Academic Language Proficiency	Dynamic Assessment Prompts
Steps 6 through 8			
After ten to fifteen minutes of exploration, student recorders come to the board and draw what their boxes look like inside.	Symbolization Representation	(no verbalization necessary)	"Have you included enough detail for others to understand your drawing?" "Does your drawing show everything you think is inside the box?"

FOSS Black Box Activity	Cognitive Functions	Cognitive Academic Language Proficiency	Dynamic Assessment Prompts
Steps 9 through 12			
Students tell what senses they used to explore the boxes. They demonstrate the techniques they used.	Labeling *"We felt the marble hit the obstruction."* Semantic / Lexic *"What I mean is . . ."* *"In other words . . ."* Logic *"Because of that . . ."* *"That's why . . ."* *"That made me think . . ."*	Model Representation Strategies Techniques Sequence words: (first, next, last, etc.) Words to describe senses (listened, felt, etc.)	"When you touch something with your hands what sense are you using?" "What other senses might you use?" "What did you do after you shook the box?"

FOSS Black Box Activity	Cognitive Functions	Cognitive Academic Language Proficiency	Dynamic Assessment Prompts
Steps 13 through 16			
Students join others who investigated a box with the same letter label on their box (all As together, all Bs together, etc.) They should work together until they reach a consensus for a model.	Test hypotheses *"I noticed . . ."* *"To find out I will . . ."* Flexibility *"Well I could do it another way . . ."* Logic *"Because of that . . ."* *"That's why . . ."* Intellectual courage *"I'm sure I am right, because . . ."*	Consensus Conference group Refine	"Listen to what the others in your group are saying. What have they said that you have not tried yet?" "How do you know you are right?"

FOSS Black Box Activity	Cognitive Functions	Cognitive Academic Language Proficiency	Dynamic Assessment Prompts
Step 17			
One recorder from each group draws the consensus model on the board.	Symbolization Representation	(no verbalization necessary)	"How can you show, in your drawing, that the marble moves?"

FOSS Black Box Activity	Cognitive Functions	Cognitive Academic Language Proficiency	Dynamic Assessment Prompts
Steps 18 through 21			
Students share ideas about how to improve their models.	Precise language *"The obstruction is triangular."* *"Our model shows . . ."* Intellectual humility *"What would you suggest?"* *"Would you help me figure out . . ."*	(all terms as established above)	"What part of this activity would you like to further study?

Appendix B

Activities To Support English Language Learners

WORD BANK

Materials: Large chart paper, markers.

Objective: Students will develop vocabulary by suggesting words for inclusion on word bank based on BLACK BOXES activity.

Language Functions: listen actively, follow directions, give information.

Develop a word bank with students. This activity can be done with the whole class, or in a small group setting with only your English language learners.

On a large piece of chart paper, record key vocabulary students will need to use in their discussions, oral reports, and writing. Next to each word include a simple drawing to illustrate the word.

Spend time with students reviewing the word bank. Read each word and briefly discuss its meaning as used in the black boxes activities. To assess students' understanding of the word bank, ask each to walk to the word bank and locate a word you name (i.e.: "Steven, would you please walk to the word bank and touch the word 'marble'?")

Sample Word Bank

black box	cardboard	conference group
corner	device	drought
funnel	hose	marble
model	obstruction	refine
representation	siphon	strategies
system	techniques	

ALPHABET BOOK

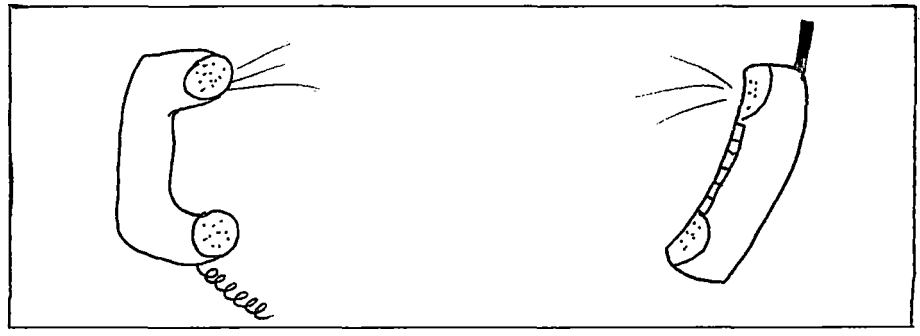
Materials: Examples of alphabet books for students to view, paper, crayons or markers for illustrating, book spine and binding machine or other book binding materials.

Objective: Students will write and illustrate one page for class book.

Language Functions: give written information to describe a black box, illustrate a black box.

A fun way to reinforce the concept of a black box and increase literacy skills at the same time is to create a class alphabet book. For each letter of the alphabet students supply an example of a black box. Each student writes and illustrates one page. Pages are then assembled in alphabetical order, bound into a book, and placed in the classroom library. Students can find learning opportunity and enjoyment in making their own alphabet books.

example:



T is for telephone.

The telephone is a communication device which allows people to talk to other people who are far away. Voices travel through the receiver, across telephone wires, and then to the receiver of the other person.

WORD OF THE DAY

Materials: small bulletin board labeled "Word of the Day" or index card with the word of the day written on it, rewards (such as raffle tickets).

Objective: Students will use key vocabulary word accurately in sentence according to teacher's directions.

Language Functions: follow directions, use accurate sentence structure.

Each day the teacher selects one word which has been used in class studies as the "word of the day." The word bank is a terrific place to get words! This word can be posted on a bulletin board or kept in the teacher's pocket on an index card. During non-instructional time (recess, free time, etc.) students come to the teacher and ask, "What is the word of the day?" The teacher tells them the word and the student must then use the word in a sentence. Stipulations can be added to increase the level of difficulty. For example, the teacher might insist that today's word must be used in a sentence which defines the word, or that today's word must be used in a sentence which is formulated in the past tense. When students accomplish the task (use the word correctly in a sentence) they are given a small reward such as a raffle ticket, or other class incentive. There are many possible variations on this game.

Here are a few more:

- The word of the day must be written on a piece of scratch paper five times. Students sign their names on the papers and deposit them in a box. At the end of the day one paper is drawn as the winner of a special prize (a piece of candy, or a "No Homework Pass").
- The word of the day must be spelled correctly to the teacher.
- The word of the day must be used in a rhyming sentence. ("The model was found in a bottle.)

GROUP SEQUENCE

Materials : slips of paper for students' writing (provided below), glue, background paper 18" x 24" construction paper.

Objective: Students will write two events that happened during their investigations with the black boxes, listen to and discuss all events written by group members, and sequence the events in the order they occurred.

Language Functions: listen actively, engage in discussion, sequence events.

Each group member records two events that happened during the Black Boxes investigations. The slips of paper with these events are then placed into a container and drawn out in turn by group members so that each person has two event slips written by someone else. The group then works together to placed all events in their logical sequence according to the events of the prior investigations. (Duplicates may be placed together.) Group members should listen carefully to events as they are read to determine whether the ones they have should be placed before or after the one being discussed. Papers can be glued in order on a background piece of construction paper (18" x 24").

*Adapted from Reading-A Novel Approach by Janice Szabos

INTERVIEWS

Materials: paper, word bank, cassette tapes and tape recorder or video tapes and camera.

Objective: Students will write questions about black boxes. Students will work with partner to pose and answer questions.

Language Functions: exchange greetings, listen actively, role play, ask questions, respond to questions.

To help students develop vocabulary in context, have them imagine that they are news reporters for a national television channel. They have been assigned to cover the National Black Box Convention. Have students write five to ten questions they would ask the researchers of the black boxes. Be sure they include key terms (see word bank list) in their questions.

Once students have written their questions, organize them into teams of two to interview classmates (the two students should be from different cooperative groups). One student takes the part of news reporter, and the other student becomes the black box researcher. The reporter interviews the researcher, asking the pre-written questions. Roles are then reversed, and the second student then becomes the reporter.

Allow students an opportunity to practice their interview techniques until they are comfortable with their questions and answers in the respective roles. Record each student's interview on cassette tape or video camera. These recordings can be a fun, interesting, academic addition to Open House or other functions which involve parent visitation.

WORD SEARCH PUZZLE

Materials: word bank, word search puzzle grid.

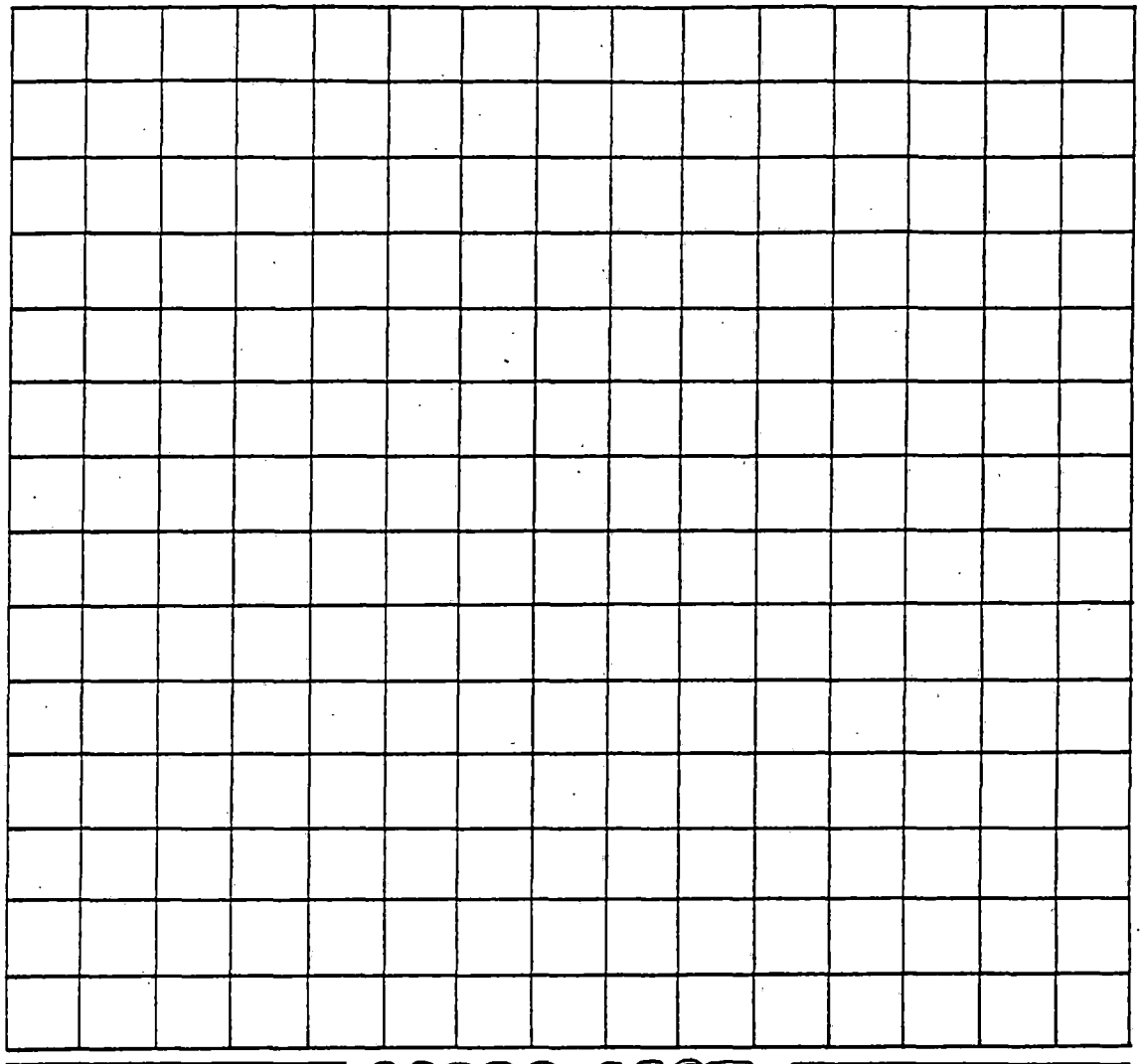
Objective: Students will write word bank words in puzzle grid then exchange with a friend and solve their puzzle.

Language Functions: exchange social courtesies with peer (to exchange puzzles).

Students can practice new vocabulary words from the word bank by creating a word search puzzle. Students write words one letter in each box. Words can be arranged horizontally, left to right or backwards, right to left. Words can also go vertically, up or down, or diagonally. Once words have been entered into the grid have students fill in the remaining boxes with letters in random order. Word searches can then be exchanged with other students to solve.

Use new vocabulary words to create a . . . .

WORD SEARCH.



WORD LIST

LETTER WRITING

Materials: paper, word bank, names and addresses of letter recipients, envelopes, stamps (if needed).

Objective: Students will write letter explaining their recent investigations with black boxes.

Language Functions: listen actively, follow directions, employ writing conventions and use letter format.

Letter writing provides good practice in vocabulary use, writing conventions, and reading. Letters are almost always viewed as welcome reading material. The thought of receiving a response to a letter can also be a powerful motivator for writing. Children can write to each other or to pen pals already established. This lesson provides one of many ways to involve English language learners in letter writing.

Tell students that they will be writing a letter to someone who knows very little about black boxes. The purpose of the letter is to tell the reader about recent class activities with black boxes. The letter should tell the reader what the students did while investigating their black boxes, as well as what the students learned from their experiences. Tell students to be sure to include key vocabulary along with relevant explanations of terms which might not be known by the reader. The letters can include an invitation to the reader to visit the classroom, meet the students, and see a demonstration of the students' black boxes.

The students' parents are a natural possibility for letter recipients. Another idea is to have each student write to a different person at their school site. Be sure to include teachers, administrators, parent volunteers, custodians, librarian, secretaries, etc. (It's a good idea to prepare these recipients in advance for this activity! Explain the lesson, and ask for their support in writing a brief response letter to the student.) Another interesting possibility is to establish computer pen-pals for your students! They could e-mail each other, send pictures, chat, etc.

HEADLINES

Materials: newspaper, prepared bulletin board, paper, markers.

Objective: Students will work with partner to create a headline describing some aspect of their black box investigation.

Language Functions: listen actively, follow directions, engage in discussion with partner, use key vocabulary to create headline.

Bring in a recent newspaper and read some of the more interesting headlines to the students. Discuss the style of writing used in creating headlines. Be sure students understand this genre as different from the articles which follow the headlines.

With the students, create some headlines about a story you have shared recently or a theme you have explored (not the black boxes!). Use these examples to illustrate how to use key vocabulary and catchy phrases to attract the reader's interest.

Show the students a bulletin board you have prepared on which they will place their headlines. Encourage them to work in teams of two to develop one or more headlines which tell something about their black boxes and/or their recent investigations in science. Provide time for students to design and create their headlines. Assist students with the placement of their headlines on the bulletin board.

This activity can be further extended by having students choose a headline from the bulletin board and write an article to accompany it. A class newspaper that can be duplicated inexpensively and shared with others makes an excellent project to give a unifying purpose for developing students' communication skills.

**Adapted from Writing is Reading: 26 Ways to Connect, by Eileen Tway.

Appendix C

Tools For Teachers

Concept Attainment Rubric

Use this rubric to score students' Extension functions (written or verbal responses to science activities). This could be used as students present their oral reports to the class, or after students have responded in writing to prompts such as "Describe a black box and give an example of one." Be sure to explain the rubric to students before using it to increase their understanding of the task.

3 = Two or more accurate ideas expressed.

2 = One accurate idea expressed.

1 = No accurate ideas expressed.

Concept Attainment Rubric

3 = Two or more accurate ideas expressed.

2 = One accurate idea expressed.

1 = No accurate ideas expressed.

Science Processes Observation Checklist

Name_____ Date_____

Activity_____

Observing: Using one or more of the five senses to gather information. May include the use of equipment.
Controlling Variables: Isolating one or more critical features in order to test it.
Comments:

_____
_____
_____

Communicating: Giving or exchanging information verbally, orally and/or in writing. Naming and describing objects.
Defining Operationally: Explaining terms accurately in order that others can share the same understanding.
Comments:

_____
_____
_____

Comparing: Assigning objects a one-to-one correspondence or comparing groups of objects according to quantity. Measuring objects by units which may or may not be standardized.
Comments:

_____
_____
_____

Ordering: Organizing according to chronological sequence. Includes seriating (large to small, etc.).
Comments:

_____
_____
_____

Science Processes Observation Checklist (continued)

Categorizing: Grouping objects or events based on attributes or characteristics. Classifying according to similarities.
Comments:

_____
_____
_____

Relating: Finding cause and effect relationships between two separate objects or events.
Formulating Hypotheses: Guessing about the relationship between variables.
Comments:

_____
_____
_____

Inferring: Developing ideas based on observations. Requires evaluation and judgment based on past experiences.
Interpreting Data: Making inferences and drawing conclusions based on logical thought.
Comments:

_____
_____
_____

Applying: Developing strategic plans and inventing new methods based on prior experiences. Using prior knowledge in a new and unique situation.
Experimenting: Combining all science processes to test hypotheses and establish the basis for conclusions.
Comments:

_____
_____
_____

Cognitive Functions Observation Checklist

Name _____

Exploration	Openness	Open to new ideas; willing to explore
	Focus	Attends to task
	Pre-Analysis	Scans for critical features of a problem
	Multiple Sources	Attends to two or more sources of info.
	Spatial	Understands spatial or topological info.
	Temporal	Understands time cues or series
	Symbolization	Understands / generates symbols
	Organized Invest.	Searches systematically, methodically
	Information Input	Gathers data accurately, credibly
	Selective recept.	Chooses essential / key elements
	Labeling	Labels elements to facilitate thinking
	Semantic/lexic	Defines terms, concepts, meanings clearly
Elaboration	Problem defin.	Specifies the task or root question
	Working memory	Sustains mental elements while thinking
	Maintain mentation	Defends against interruptions
	Expansion	Builds on thoughts
	Flexibility	Considers possible multiple viewpoints
	Metaphor. think.	Exercises cross-domain analogies
	Comparison	Describes relation of two things
	Categorization	Places objects/events in group or order
	Logic	Supports thinking with reason
	Summary	Extracts or synthesizes main idea
	Planning	Determines parts, sequence of plan
	Formulates Hypo.	Guesses about relation. between variables
	Tests hypothesis	Establishes basis for conclusions
	Perseverance	Follows through on plans
	Outcome eval.	Assesses solution
	Recycle for input	Recognizes need for more information
	Implication	Weighs consequences of decision
	Transfer	Applies prior knowledge to current data
	Decision	Decides when to bring closure
	Representation	Uses images or other forms for thought
Extension	Representation	Communicates/transports mental process
	Rehearsal	Thinks before expressing/restrains impulse
	Adapted language	Explains understandably to audience
	Precise language	Expresses self accurately
	Intellect. cour.	Defends ideas / solutions
	Self-monitoring	Regards consequences of own behaviors
	Intellect. hum.	Solicits/is open to external feedback
	Self-correcting	Changes behavior following mistakes

**Adapted from Scientific Talent Enriched Performance System -Cognitive Functions of Scientific Thinking, by L. T. Díaz-Rico.

Dynamic Assessment Questions

These questions can be used to gain an in-depth assessment of individual learners as they work through an investigation or problem. This could be used for teacher notes about individual students, or as a written assignment for the entire class.

Name _____ Date _____

Activity _____

1. What is the problem you are solving?

_____
_____
_____

2. What did you do when you were first given this problem?

_____
_____
_____

3. Why did you do that first?

_____
_____
_____

4. Tell me what you see and what you are thinking about as you solve this problem.

_____
_____
_____

5. How is this problem the same as another you have solved before?

_____
_____
_____

6. What did you do to solve that problem that you could do now to help you solve this one?

_____
_____
_____

7. Tell me what you mean when you say _____?

_____
_____
_____

Dynamic Assessment Questions (continued)

8. Do you have any other ideas about how to solve this problem?

9. Are there any other possibilities?

10. Why do you think the solution you chose is correct?

11. Why is that one correct, and the others wrong?

REFERENCES

American Association for the Advancement of Science. (1965). The psychological bases of Science-A Process Approach. Washington, D.C.: Author.

Campione, J. & Brown, A. (1984). Learning ability and transfer propensity as sources of individual differences in intelligence. In P.H. Brooks, C. McCauley & R. Sperber (Eds.), Learning and cognition in the mentally retarded (pp.311-332). Baltimore: University Park Press.

Campione, J. & Brown, A. (1990). Guided learning and transfer: Implications for approaches to assessment. In N. Frederiksen, R. Glaser, A. Lesgold, M. Shafto (Eds.), Diagnostic monitoring of skill and knowledge acquisition (pp.141-172). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Carter, D. & Wilson, R. (1992). Minorities in higher education. Washington, D.C.: American Council on Higher Education.

Chamot, A., & O'Malley, J. (1987). The cognitive academic language learning approach: A bridge to the mainstream. TESOL Quarterly, 21(2), June, 227-249.

Cohen, E. (1994). Designing groupwork: Strategies for the heterogeneous classroom. New York: Teachers College Press.

Cummins, J. (1981). The role of primary language development in promoting educational success for language minority students. In Schooling and language minority students: A theoretical framework (pp. 3-49). Los Angeles: Evaluation, Dissemination and Assessment Center, California State University.

Day, B. & Drake, K. (1986). Developmental and experiential programs: The key to quality education and the care of young children. Educational Leadership, 44, 25-27.

Day, J. & Hall, L. (1987). Cognitive assessment, intelligence, and instruction. In J. Day and J. Borkowski (Eds.), Intelligence and exceptionality: New directions for theory, assessment, and instructional practices (pp. 57-80). Norwood, NJ: Ablex Publishing Corporation.

Díaz-Rico, L. & Weed, K. (1995). The crosscultural, language, and academic development handbook. Boston, MA: Allyn and Bacon.

Encyclopaedia Britannica Educational Corporation. (1992). Full option science system. Chicago: Author.

Ennis, R. (1987). A taxonomy of critical thinking dispositions and abilities. In J. Baron & R. J. Sternberg (Eds.), Teaching thinking skills: Theory and practice (pp. 9-26). New York: W. H. Freeman & Co.

Feuerstein, R. (1980). Instrumental enrichment: An intervention program for cognitive modifiability. Baltimore: University Park Press.

Gagné, R. M. (1964). Psychological issues in Science-A Process Approach. In American Association for the Advancement of Science, The psychological bases of Science-A Process Approach (pp. 1-8). Washington, D.C.: Author.

Hall, L. & Day, J. (1984). Proximal development in learning disabled, educable mentally retarded, and average school children. Manuscript submitted for publication.

Halliday, M. (1978). Language as a social semiotic. Baltimore, MD: University Park Press.

Hickson, J. & Skuy, M. (1990). Creativity and cognitive modifiability in gifted or disadvantaged pupils: A promising alliance. School Psychology International, 11(4), 295-301.

It's elementary! Elementary grades task force report. (1992). Sacramento, CA: California Department of Education.

Kaniel, S. & Reichenberg, R. (1990). Dynamic assessment and cognitive program for disadvantaged gifted children. Gifted Education International, 7(1), 9-15.

Kessler, C., Quinn, M., & Fathman, A. (1992). Science and cooperative learning for LEP students. In C. Kessler (Ed.), Cooperative language learning (pp. 65-83). Englewood Cliffs, NJ: Regents-Prentice-Hall.

Lajoie S. & Lesgold, A. (1992). Dynamic assessment of proficiency for solving procedural knowledge tasks. Educational Psychologist, 27(3), 365-384.

Lidz, C. (1987). Dynamic assessment: An interactional approach to evaluating learning potential. New York: Guilford Press.

Reilly, T. (1988). ESL through content area instruction. Washington, D.C.: Office of Educational Research and Improvement.

Scholastic Science. (1993). Science Place. Philadelphia, PA: Author.

Science framework for California public schools. (1990). Sacramento: California Department of Education.

Sternberg, R. J. (1985). Beyond IQ: A triarchic theory of human intelligence. New York: Cambridge University Press.

Sternberg, R. J. (1987). Teaching intelligence: The application of cognitive psychology to the improvement of intellectual skills. In J. Baron & R. J. Sternberg (Eds.), Teaching thinking skills: Theory and practice (pp. 182-218). New York: W. H. Freeman & Co.

Vygotsky, L. (1978). Mind in Society: The development of higher psychological processes (M. Cole, V. John-Steiner, S. Scribner, & E. Souberman, Eds. and Trans.). Cambridge, MA: Harvard University Press.